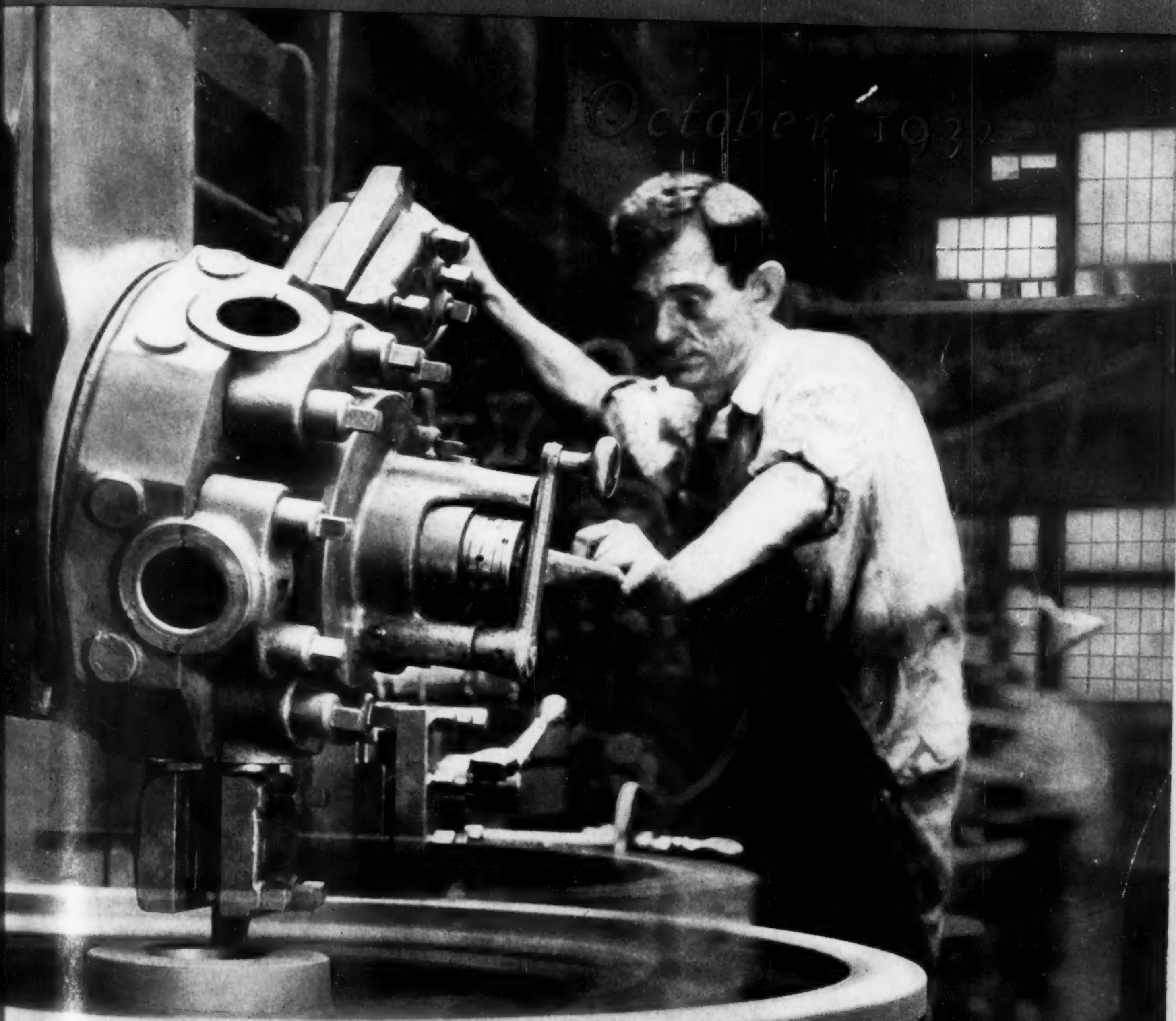
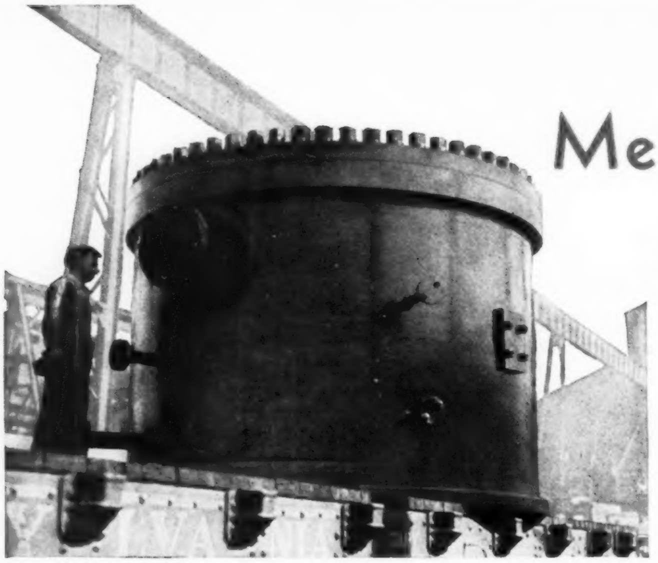
MECHANICAL ENGINEERING





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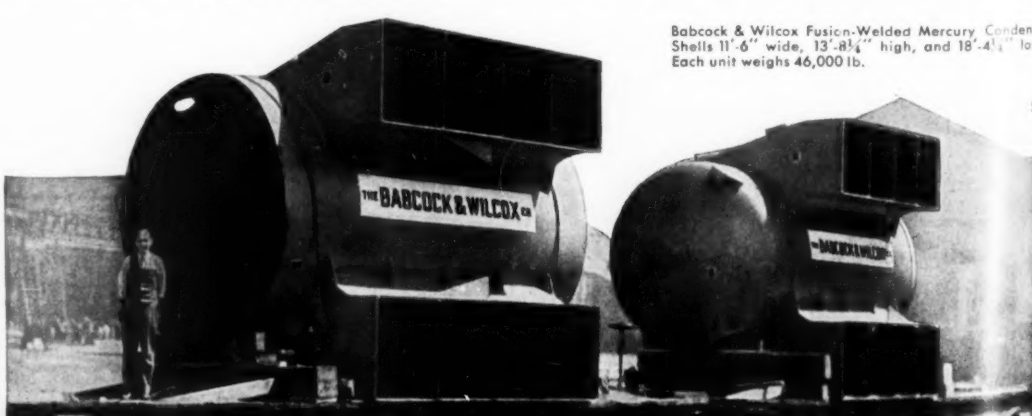
S-3



MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 54 NUMBER 10

Contents for October, 1932

Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of addresses must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B2, Par. 3). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

From an engraving by William Hogarth, 1747, in the collection of H. R. Taube, who provides the month's leading article on the early textile industry

A CHALLENGE TO YOUTH

FOR the first time—and under an arrangement recently provided by the Council of The American Society of Mechanical Engineers—MECHANICAL ENGINEERING is being distributed extensively to certain groups of engineering students affiliated with the Society through its Student Branches. This October issue therefore marks an important event in the development of the Society's journal which it is appropriate to signalize. Maturer readers, familiar with these pages, will appreciate the significance of the addition of a few thousand men of college age to the group to whom MECHANICAL ENGINEERING is distributed. For these younger men are the future engineers. The hope of the future is with them. The times they face offer them a challenge, which is economic and humanitarian in its nature as well as technological.

WHAT is MECHANICAL ENGINEERING that students should become acquainted with it while still at college, and as practicing engineers retain their interest in it? It is a professional magazine for the mechanical engineer. It does not confine itself to one or a few branches of mechanical engineering, to mechanical engineering in a narrow sense, or even to engineering in a technological sense. It treats of a tremendous variety of technical subjects, of the fundamental sciences of engineering, and of the economic, social, and political aspects of engineering. It attempts to coordinate the interests of the individual with those of the profession, and those of the profession with those of the world at large. It discusses subjects that affect engineers as a group of professional men.

TWO hundred years ago the foundations of our present industrial era were being laid in the introduction of the machine to production methods. Throughout the Industrial Revolution, as this historic period in human affairs has since been called, engineer after engineer and machine after machine appeared to upset the economic balance momentarily maintained during some breathing spell in rapidly advancing industrial and social progress. Important among these early influences was the fly shuttle, which made it possible for the weaver to outstrip the industry of spinners and led directly to

the development of the spinning machine by Richard Arkwright. The consequences of these changes and the conditions out of which they grew are set forth by H. R. Taube in the leading article in this month's MECHANICAL ENGINEERING.

ARKWRIGHT does not appear to have been a man with a high moral purpose. On the contrary, it is plain that he was acquisitive and self-seeking. When he built his mill at Cromford, thus introducing machine-production methods of manufacture, he probably had no conception of the profound change that he was working in the history of civilization. But he set forces at work by that act that have both blessed and plagued the world ever since. By the solution of one mechanical problem he immediately stirred up countless others, social and economic as well as mechanical. Some of those problems became and are today of major importance to humanity. Combined with unlimited power, which Watt contemporaneously made possible, the machine has vastly multiplied the productivity of human labor while practically eliminating the physical fatigue accompanying that labor. Undreamed-of standards of living have been attained, and even higher are possible as a consequence of this combination working under the direction of trained intelligences. But with the possibility that exists of supplying abundantly all of the material wants of humanity, machinery is now idle and human beings live in squalor and want. The Lancashire towns in which Arkwright's machinery was first used, today are seething with social disorders that make impossible the profitable operation of their modern mills. Machinery has outstripped social progress, and has become an even more important element in industrial and economic life. Engineers cannot overlook this fact, nor should they seek to escape the obligation that rests upon them to assist in attempting to set matters right and keeping them so as best they can.

THIS is a challenge to youth. It cries out from the scenes that reflect the times in which we live. Intelligence and sound judgment, patience, and sympathetic understanding are sorely needed. No simple analysis can be made—no single or permanent solution can be found. Just as the weavers, with improved looms, were able to weave more cloth than could be made from the yarn the spinners were able to supply them prior to the introduction of the spinning machine, when the tables were turned and the loom had to be improved to keep up with the spinners, so do the improvements of today stimulate those of tomorrow. And just as those crude machines of the eighteenth century caused far-reaching social and economic disturbances, so do the more rapidly developing machines of today upset social and economic equilibrium.

IT IS FAIR to wonder what differences there might have been in the history of the past 150 years had Arkwright been a man with high social ideals and a constructive economic philosophy. The limitations of human intelligence are such that all of the baneful influences of the introduction of machine production could not have been avoided. But as humanity understands more clearly the effects of invention and machinery on its welfare and progress, it seems reasonable to expect that more intelligent and sympathetic attention will be given to social and economic disorders arising out of technological advances. Youth will, perforce, find itself grappling with these problems as it takes its place in the world. The challenge is in the times, and particularly in the engineering career.

WHAT, then, must be the equipment of those who accept the challenge? Dr. Harvey N. Davis, President of Stevens Institute of Technology, took this up in an address at the commencement exercises of Haverford College last June. The address constitutes the second article in this month's issue. Dr. Davis made an appeal to young men to think constructively, to study modern economics, and to formulate for themselves some unifying economic principles.

MECHANICAL ENGINEERING has been trying to assist its readers to formulate such principles by drawing attention to social and economic problems. No profession is greater than the greatness of the men who engage in it can make it, and if these men adopt the narrow view, the influence of their profession will be narrow. In the September, 1932, news letter of the National City Bank of New York, in a discussion of inflation and its results, the writer speaks of the "influence of improvements in production" as "the one constant factor which amid all the illusions has been producing real economic gains." For such improvements in production, engineers are generally responsible; yet small voice have they in the councils of those who most directly attempt the control of our economic destinies. Here is another challenge to youth, to broaden the influence of its thinking and impress it upon the world of affairs.

PERHAPS too close an absorption with the machine has dulled the minds of engineers to their larger function. The machine is merely one of many factors in human affairs. Engineering is not a culture that holds its reason for being within its own development. Without the larger purpose of the attainment of human satisfactions, the machine is nothing. Behind it, above it, served by it, is man himself. No engineer will have served his larger usefulness if he forgets humanity itself. Our cover picture suggests this relationship.

A Section of the Salt Springs–Tiger Creek Conduit

(*See paper by F. A. Allner on "Hydroelectric Developments," page 695*)

RICHARD ARKWRIGHT
and the Early Years of the
INDUSTRIAL REVOLUTION

By H. R. Taube[1]

TWO HUNDRED years ago there was born the man who more than any other individual, with the possible exception of James Watt, is entitled to the claim of having laid the foundation of modern industry as characterized by consistent division of labor, the mechanization of the processes of production, and their concentration in time and space. This man was Richard Arkwright, whose name in popular belief is identified, though as we shall see later, erroneously, with the invention of the water frame, the first spinning machine adapted for power drive, and mass production. His fame and significance, however, do not rest upon his achievements as a creative inventor, but upon his having been the first to visualize and fully appreciate the economic possibilities of machine production.

Richd Arkwright

For a better appreciation of Arkwright's life work and of the outstanding position which this prototype of the modern captain of industry occupies in economic history, it is necessary to give a brief account of industrial organization and technique in 18th century England. The still uncompleted economic, social, and technological changes which began in the second half of the 18th century and which we call the Industrial Revolution, are of more than local interest, being the prelude to similar events in all countries of the Western world. Even what is today happening in this country is only, as Prof. Wesley C. Mitchell says, "the latest phase of cumulative processes which have dominated Western life since the Industrial Revolution got under way." In the sense that ancient Greece is the classic country of sculpture, or Germany of music, so England is the classic country of industry and engineering, and for this reason the early history of engineering and industry, in common with the early history of other elements of life and culture, contains lessons which should help us in a better understanding of our own problems.

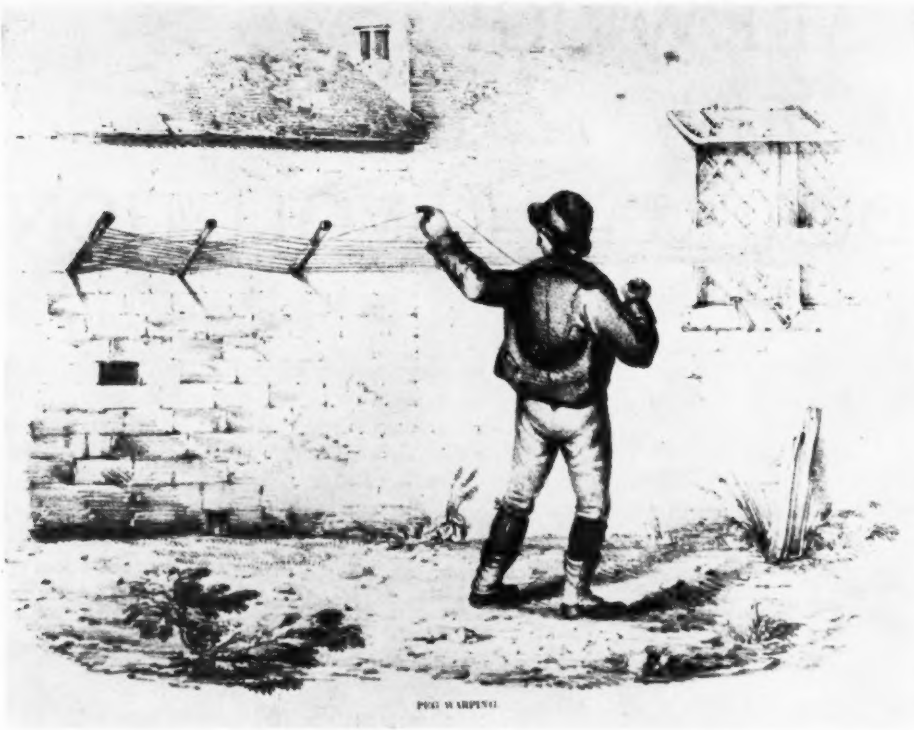
THE TEXTILE INDUSTRY IN ENGLAND PRIOR TO THE INDUSTRIAL REVOLUTION

For centuries the staple industry of England was the production of woolen goods. One of the centers of this industry was in the southwest of England, where capitalist clothiers, using mostly Spanish wool and exporting to foreign markets, supplied the raw material to the spinners and weavers. Another center, rapidly growing in importance, was in the north, in Yorkshire, Lancashire, and Derbyshire, where wool grown in the neighborhood was used by independent craftsmen, working in their homes.[2] The manufacture was carried on mostly in the country, in hundreds of hamlets and villages, by yeomen and cottagers who generally had an agricultural bye employment. In the course of the century the number of families entirely dependent for their livelihood on their trade was steadily growing, their ranks being swelled by many thousands of little landholders expropriated as a consequence of the land-enclosure acts.

The father and the sons worked at the loom, and

[1] Combustion Engineering Corporation, New York, N. Y. Formerly Vice-President, Dvigatel Car Co., Petrograd, Russia, and Reval, Estonia. Mem. A.S.M.E.

[2] See Frank Podmore, "Robert Owen," 1907, vol. 1, p. 31.



WHEN WARPING WAS DONE BY HAND[3]

The threads of the warp were divided by the pegs, each alternate thread going under the center peg, and the succeeding thread over it. This division of the threads, called the "lesse," was preserved during the weaving. At the other end of the warp the threads were passed round two pegs in a similar manner.

women, children, and old people were engaged in spinning and carding. As it took from six to eight hands to supply one loom with yarn there was work enough for every person from seven to eighty years of age.[4] The equipment used in this industry was very primitive and practically the same as in the time of the Pharaohs, with the exception of the spinning wheel, which in the 16th century had begun to replace the prehistoric distaff. The hand loom, the spinning wheel, and the cards for combing the wool were so simple that every village carpenter could make them, and were cheap enough to enable the poorest weaver to acquire the equipment for his workshop.

In the second half of the 17th century cotton began to challenge the monopoly of wool. The East India Company imported great quantities of printed and painted cotton cloth, and this became very fashionable. The woolen industry, which guarded jealously its interests and was always ready to invoke the law to protect itself, appealed to Parliament, and in 1700 a law was enacted prohibiting the importation of printed cottons. This embargo did not fail to encourage the domestic manufacture of these goods which, though inferior in quality, found a ready market.

This new industry established itself in and near Manchester, being supplied with raw cotton from near-by Liverpool by merchants who imported it from India and the West Indies. The local craftsmen had no difficulty in adapting themselves to the new raw material, as its use required neither new equipment nor a radically different technique.

The woolen trade tried to stem the growing tide of cotton and succeeded in securing the passage of a law prohibiting the domestic manufacture of printed and painted cotton cloth. In 1736 this law was amended, exempting from its restrictions cloth having a linen warp and a cotton weft, the so-called fustians, fabrics that were manufactured in great quantities.[5]

Originally the weavers bought their own raw cotton and linen yarn, mostly imported from Germany and Ireland, and sold their cloth to the merchants at the weekly markets. But, owing to the growing complexity of conditions, the buying of the raw material and the sale of the manufactured product began to require more capital, business ability, and time than the average weaver could command. This situation led to the appearance of a new economic factor, the merchant manufacturer. "It was not until 1740," writes Richard Guest,[6] "that the Manchester manufacturers began to give out warp and raw cotton to the weavers, receiving it back from them in cloth and paying for the carding, roving, spinning, and weaving. The merchants dyed the fustians and then carried them to the principal towns in the kingdom on pack horses." Only after the middle of the century were the roads sufficiently improved to make wheel traffic possible, and the merchants began to carry with them only samples, forwarding later by wagon the goods sold during their journey.

THE ADVENT OF THE INVENTOR

From the ranks of these small capitalists came, a generation later, most of the men endowed with the business acumen and organizing ability required to put to work the mechanical inventions which began to

[3] The illustrations accompanying this article, with the exception of the portrait of Richard Arkwright and the picture of his Cromford Mill, which are from old prints, have been reproduced from Guest's "Compendious History of the Cotton Manufacture."

[4] See Will. Radcliffe, "Origin of Power-Loom Weaving," 1828.

[5] Paul Mantoux, "La Révolution Industrielle au 18e Siècle," p. 193.

[6] Richard Guest, "Compendious History of the Cotton Manufacture," Manchester, 1823.

appear at this time. The inventors, with the exception of Watt and Cartwright, were simple craftsmen—weavers, carpenters, millwrights—interested in the practical solution of some problem of their trade, men who, to quote Mantoux, personified the practical empiricism of the English people. "These inventions may be sufficiently explained by the economic necessity and the spontaneous efforts which call them forth. Every technical problem is first of all a practical problem. . . . The history of inventions is not only a history of the inventors, but the history of the collective experience which step by step solves the problems raised by collective needs."[7] The history of the cotton industry furnishes convincing proof of the truth of this view.

SPINNING BEFORE ARKWRIGHT'S TIME

The cotton after being combed or carded between the hand cards, was scraped off them in rolls about twelve inches long, and three-quarters of an inch in diameter. These rolls, called cardings, were drawn out into rovings on the hand wheel. In Figure 2 the cardings are represented lying across the knee of the rover. From the spindle of Figure 2 the rovings were taken to Figure 3, to be spun into weft. In Figure 3 the roving lies in the lap of the spinner. On the spindle of Figure 3, the weft was finally prepared for the weaver. In roving, the cardings were drawn out at an angle of forty or forty-five degrees from the point of the spindle; in spinning, the rovings were drawn out nearly at a right angle. The hand wheel was first used in the woolen manufacture.

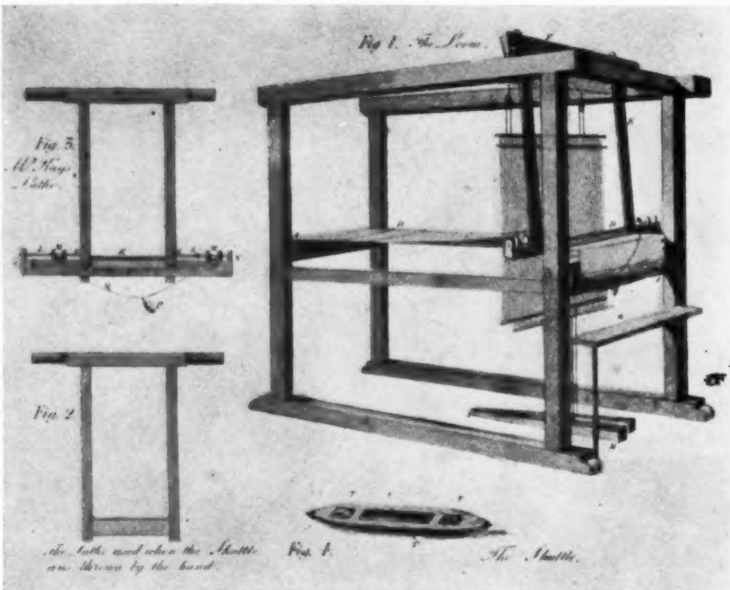
In weaving cloth above thirty-six inches wide, two men were required to one loom because one man could not extend his arms sufficiently to throw the shuttle through the warp from one hand to the other. John Kay, a weaver of Bury, overcame this difficulty by a simple and ingenious device, the fly shuttle, which he invented in 1733. The fly shuttle not only made possible the weaving of cloth of any width by one man, but also doubled the output of the loom. We have seen that it required from six to eight workers to supply yarn for one weaver. The increased output of cloth therefore caused a lag in the supply of yarn, thus throwing the whole industry out of balance. The price of yarn rose, and frequently it became impossible to obtain the necessary quantity in a given time.

By about 1760 the fly shuttle had come into general use and the necessity for some means to overcome the shortage of yarn became an urgent problem, eagerly discussed in every inn and workshop throughout Lancashire. Many would-be inventors at that time must have tried to invent a spinning machine, and three of them, all Lancashiremen, Highs, Hargreaves, and Arkwright, in rapid succession, came forward with such machines.

The first spinning machine, constructed in 1764 by Thomas Highs, a reed maker, of Leigh, with the assistance of John Kay, a clock maker and namesake of the inventor of the fly shuttle, was in fact only a multiple-spindle spinning wheel. And so was also James Hargreaves' machine invented in 1767, which was a modification and improvement of Highs's spinning jenny, so called, according to Guest, after his daughter Jane. Hargreaves' machine was easy to build and suitable for hand drive. It therefore quickly found its way into the workshops of the village craftsmen, and at the same time larger models with numerous spindles were built for the use in water-driven mills which began to appear in increasing numbers. However, the yarn produced by the spinning jenny was suitable only for wefts. To make a stronger yarn that could be used for warps a spinning machine based upon a different principle was required.

As a matter of fact, such a machine had already been invented as early as 1733 by John Wyatt, a carpenter, and patented in the name of his partner, Lewis Paul, in 1738. This machine used rollers to draw out the cotton and spindles to twist the thread. Wyatt and Paul built a small mill in Northampton, but probably owing to lack of capital and technical imperfections of the ma-

[7] Mantoux, op. cit., p. 197.



THE LOOM IMPROVED BY JOHN KAY

Before the loom was improved by John Kay the shuttle was thrown back and forth **by hand. Fig. 2 shows the lathe of such a loom, and Fig. 3 shows** Kay's lathe with **his fly shuttle. Kay added boxes at each end of the lathe, beyond the reed, in which the shuttle lay. In each box was a slide on an iron rod. The slides were fastened to the picking peg by strings** and were actuated by the jerk of the weaver's hand. This motion of the slides drove the shuttle, which was provided with rollers, across the loom along the shuttle race.

chine, this somewhat premature undertaking failed.[8] It was little spoken about, but it is nevertheless possible that Highs and Arkwright might have had some knowledge of it. At any rate it was Arkwright's good luck to hit at the right time upon the right idea which brought him fame and fortune.

ARKWRIGHT APPEARS ON THE SCENE

Richard Arkwright was born on December 23, 1732, in Preston, Lancashire, the thirteenth child of a poor family. His schooling was so defective that he could scarcely write. He was brought up to the trade of a barber and established himself in Bolton. Ambitious and enterprising, he was not satisfied with his humble calling and started traveling through the country buying human hair which he dyed and sold to the wig makers.

His first wife was a native of Leigh, Highs's home town, and thus he was brought in contact with the inventor of the spinning jenny and his assistant, Kay. In 1767 he approached the latter and hired him for the purpose of making in secret a model of a spinning machine. His business could not have been very lucrative as he did not even possess sufficient means to cover the expenses for this work, and had to ask for the financial help of a friend from Preston. The model made by Kay is probably the same one that is preserved in the Victoria and Albert Museum, in London. It is made entirely of wood and, judging by the specifications of Wyatt's patent, resembles his spinning machine in a general way. The work done by the fingers of the hand spinner consists of two distinct operations: the stretching and drawing out of a piece of carded cotton and the twisting of these drawn-out fibers into a thread. As it is impossible to accomplish this in one operation, the cotton is first spun into a coarse thread or roving which, in a second operation, is converted into the finished yarn. Arkwright's spinning machine was intended only to spin rovings into yarn, but unlike the spinning jenny it was easily adaptable to the preparation of roving. This machine substitutes for the fingers of the spinner two sets of rollers revolving with unequal velocity. The lower roller of each pair is fluted longitudinally, and the upper is covered with leather. The rear pair of rollers, which receive the cotton, revolve slower than the front pair, with the effect that the front pair, because of their greater velocity, exert a slight pull on the cotton. In other words, the front rollers draw the cotton as the fingers of the hand-spinner had done, but with far greater speed and regularity than human fingers ever attained. Beneath these rollers were spindles revolving at great speed on which the twisted thread was wound.[9]

ARKWRIGHT'S PATENTS

Arkwright was granted a patent for his spinning machine on July 3, 1769, but before he received it he had undertaken steps to obtain financial backing. Knowing the violent prejudice against machinery and the riotous temper of his fellow-Lancashiremen—only a few months before a mob had destroyed Hargreaves' little mill in Blackburn—he and Kay moved in 1768 to Nottingham, which was already at that time a center of the hosiery industry. The industry was carried on by master manufacturers who supplied the weavers not only with yarn but also with the stocking frames, primitive knitting machines invented in 1598 by one William Lee. The merchants of Nottingham had been taught by their ledgers that machines meant good business, and in consequence Arkwright had no great difficulty in finding backers for his invention in the person of local bankers, the brothers Wright. They gave him the means for setting up a small horse-driven mill, but the difficulties in transforming his small model into full-size, smoothly working machines and the organization of production must have required much time, ingenuity, and money. The financial results were not encouraging at first. The cautious bankers therefore withdrew their support and introduced Arkwright to two well-to-do hosiery manufacturers, Need and Strutt. The latter was himself the successful inventor

[8] E. Baines, "History of the Cotton Manufacture," London, 1835.

[9] Robert Dale Owen, "Threading My Way," 1874.

of a stocking frame for the manufacture of ribbed stockings and well qualified to recognize the unlimited possibilities of the new spinning machine. In 1771, Arkwright and his new partners set up a mill in Cromford, near Derby, on the river Derwent, which furnished the power for the spinning machines. Until, some twenty years later, the steam engine was introduced into the cotton industry, water power was the only source of energy available for the mills using the new spinning machines, and therefore they were called "water frames."

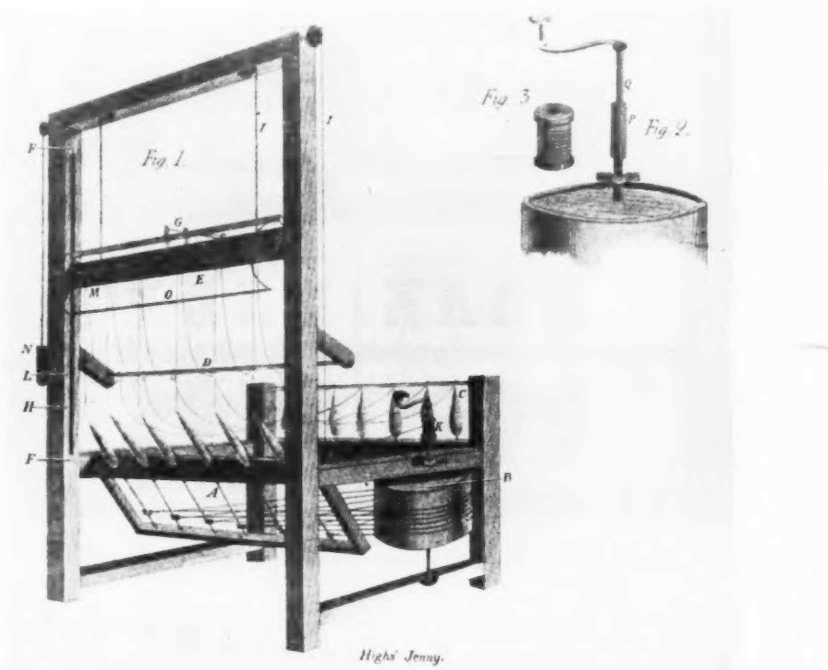
The yarn produced in Cromford was of excellent quality, much superior in strength and uniformity to the best hand-spun product. It was first used only for stockings, but as it proved to be suited for warps, Arkwright erected, in 1773, a weaving shop where all-cotton calicoes were manufactured. Arkwright's competitors did not fail to invoke against him the old statute prohibiting the manufacture of all-printed cotton cloth, and he had to petition Parliament for legislation repealing this antiquated law. The repeal was effected in 1774.

In the following year Arkwright was granted a second patent containing ten claims which covered a complete system of machinery for carding and roving cotton by a continuous and entirely mechanized process, an epoch-making step in the history of technology. Protected by his patents, Arkwright started to expand his interests, forming new partnerships and building new mills. His attempt to invade Lancashire, where he built a mill near Chorley, proved, however, to be a failure; it was destroyed in 1779 during a riot directed against the introduction of machinery.

LEGAL COMPLICATIONS

His two patents gave Arkwright practically a monopoly for machinery required in cotton spinning, but not being able himself to meet the growing demand for his high-grade yarn, he granted licenses for the use of his machinery. However, the majority of his competitors, though quite willing to reap the benefits of the use of his machines, were not enthusiastic about paying license fees and circumvented the patents by introducing minor changes and modifications. To protect his rights, Arkwright, in 1781, brought suit against nine infringers, and one of these cases was brought to trial. The defense was that Arkwright had not fully described his inventions as required by law and that, in consequence, the patents were null and void. The verdict was rendered in favor of the defendant. During the next three and a half years Arkwright made no attempts to protect his rights, which were now openly disregarded, but in February, 1785, he sued Peter Nightingale for the infringement of his second patent, the first having expired in 1783. He called several prominent engineers as experts (Guest calls them artists), among whom was James Watt, who testified that it would be possible to build the machinery with no other information than that contained in the patent. The court reversed the decision of the lower court and declared the patent valid.

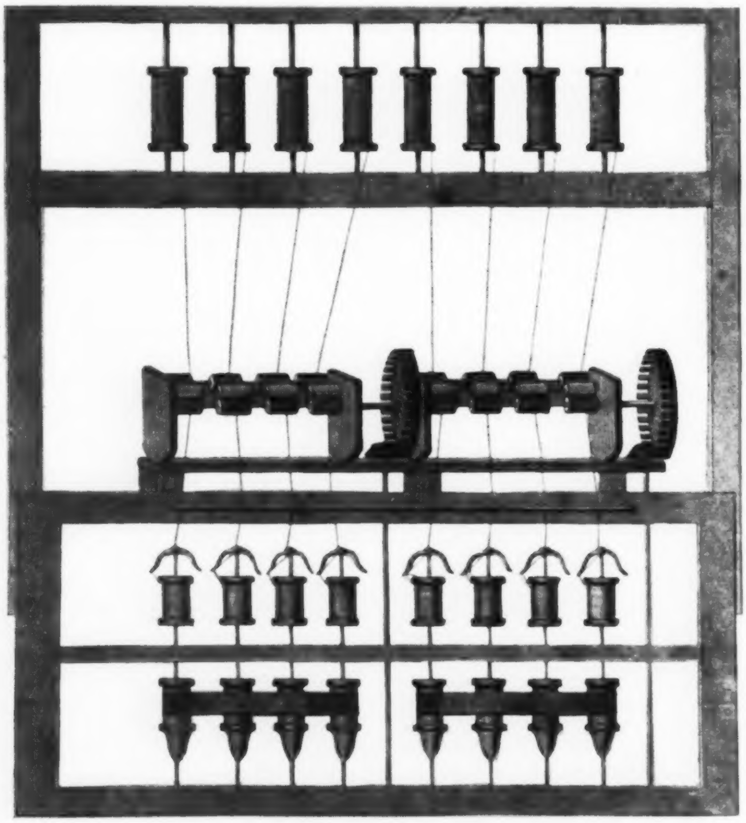
The decision caused great alarm among the cotton spinners because there was scarcely one of them who had not in some way infringed Arkwright's patent. A group of the most prominent manufacturers formed a protective association and brought an appeal which was tried in June, 1785, before the Court of the King's Bench with an impressive array of legal lights as counsel on



THE MULTIPLE-SPINDLE SPINNING MACHINE INVENTED BY THOMAS HIGHS

A, the spindles turned by strings from the drum *B*. *C*, the rovings; *D*, the wire loops; *E*, the clove which rises and falls in the groove *FF*, and is opened and shut by the latch *G*. When the clove is down at the spindles, at *H* it is opened and the drum is turned which raises the clove by means of the cord *II*, which passing over pulleys is coiled round the bobbin *K*. As the clove rises the rovings slide through it; when the clove is raised five or six inches to *L* it is shut fast by the latch *G*, the drum is again turned, which sets the spindles in motion and raises the clove by the coiling of the cord round the bobbin. The rising of the clove draws out the five or six inches of roving shut fast between the spindles and the clove into weft. When the clove is raised to *M* the roving is sufficiently drawn out; the bobbin is then moved by a latch from the lower part of the axle, nearer to the handle where the axle is of less diameter than the bore of the bobbin. The drum is then turned and the spindles again revolve, giving to the weft the necessary twist. During this twisting of the weft the clove and the bobbin remain stationary, the axle of the drum turning within the bobbin, and a leaden weight, *N*, counterbalancing the clove. When twisted, the clove is lowered from *M* to *H* by the hand of the spinner, and the weft copped or wound upon the spindles. The drop rod *O* guides the weft upon the spindles. Fig. 2. The Axle of the Drum (square at *P* and round and of less diameter at *Q*). Fig. 3. The Bobbin, which when at *P* turns with the axle, but when at *Q* remains stationary.

both sides. During the trial it was established that the roving frame covered by one of the claims was identical with the water frame, and also that the other claims had been anticipated by other inventors, a fact which had been known to the defendant when he filed his patent. The sensation of the trial was the testimony of Thomas Highs, who was at that time engineer in a cotton mill. His testimony reveals him as a simple-minded, modest man, not devoid of quiet dignity, but entirely lacking the shrewdness and aggressive acquisitiveness which Arkwright possessed in such a high degree. He said that in 1767 he, with the assistance of John Kay, had built a spinning machine identical with the one patented by the defendant two years later, and that Arkwright had induced Kay to reproduce this machine which Highs had kept secret while waiting for an opportunity to market his invention. He gave a dramatic account of a meeting he had had with Arkwright during which he had reproached him for appropriating his invention. Kay, a somewhat shifty and evasive witness, confirmed Highs's testimony. The jury, without a minute's hesitation, brought in their verdict against Arkwright and the patent was canceled.[10]



A FRONT VIEW OF THE WATER FRAME

The extremely damaging testimony, which he was unable to refute, and the heavy moral and financial effect of the court's decision, which would have ruined the average man, did not seriously affect Arkwright's business and social standing. At that time he was already a financial power and it is therefore not surprising that a year after the trial he was knighted and shortly afterward elected High Sheriff of the County of Derby. His interests were expanding rapidly, and when he died in his sixtieth year, in 1792, he left to his heirs the, for that time, enormous fortune of £500,000 and the considerable income from eight mills.

CARTWRIGHT INTRODUCES THE POWER LOOM

Arkwright's activities had made the mechanization of production an important economic factor, although at his death the process was not completed. Spinning by machine had again disturbed the equilibrium between spinning and weaving. The new cotton mills produced yarn at a rate exceeding the ability of the hand weavers to convert it into cloth. Although the number of weavers increased rapidly, there was a surplus of yarn which depressed prices to an alarming extent so that it had to be exported, much to the dismay of the cloth merchants, who feared the creation of a rival industry on the Continent. The invention of a weaving machine therefore became an urgent problem. This problem was solved by a talented amateur, the Rev. Dr. Edmund Cartwright, by the invention, in 1785, of the power loom. The active and desperate resistance of the hand weavers made its immediate introduction impossible. Only after 1800 were weaving shops equipped with power looms which, in conjunction with Crompton's spinning mule, the dressing machine, the calico printing machine, and the steam engine, completed the process of mechanization of the textile industry, the concentration of production in the factory, and its capitalistic organization. The high cost of machinery and of the buildings they required made it impossible for the individual craftsman to own the tools of production and to preserve his economic independence, although for a few decades the doomed home industry was able to carry on a losing fight against the factory system.

Contrary to general belief, the steam engine did not play any part in this first phase of the Industrial Revolution. In 1788 there existed in Lancashire alone forty cotton mills, and in England and Scotland a total of 121 mills. The first steam engine was installed in a cotton mill in 1785, and in 1790 Arkwright's order for his first steam engine brought their number up to five.[11]

[10] "Trial of a case to repeal a patent granted to Mr. Richard Arkwright," London, 1785.

[11] Conrad Matschoss, "Die Entwickelung der Dampfmaschine," p. 127.

The success of these first attempts encouraged other manufacturers to adopt steam for motive power and in the last years of the 18th century the number of steam engines in the textile industry increased rapidly. Because of the steam engine it was possible for the mills to become independent of the out-of-the-way sources of water power and to move nearer to the markets of raw material and finished product and the centers of population. Nevertheless, as late as in 1800 there were in Manchester, the center of cotton spinning, only 32 steam engines, aggregating 430 hp, and in Leeds, 20 engines, with a total of 270 hp.[12]

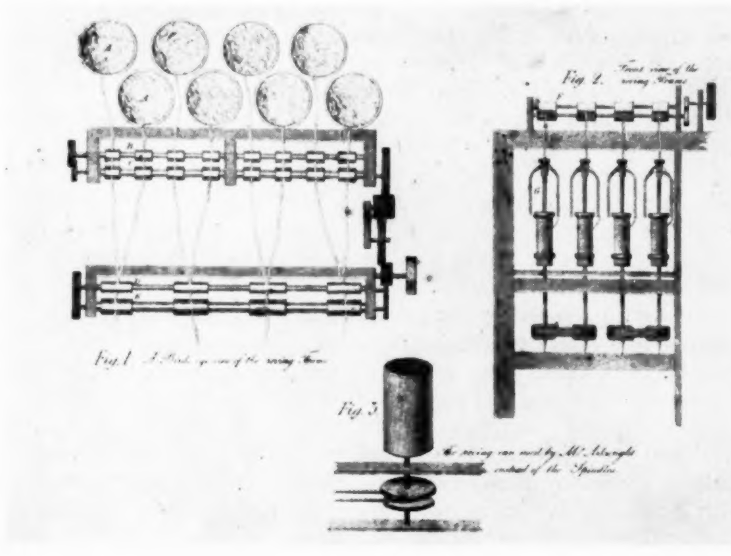
CARLYLE'S ESTIMATE OF ARKWRIGHT

Against the background of the bitter struggle between the old social and economic order and the powerful forces brought into action by the machine, Arkwright's massive and coarse figure stands out in bold relief. He was certainly not a shining example of high moral standards and sterling honesty, but his indefatigable perseverance and singleness of purpose were extraordinary. He possessed remarkable ability in managing men, and his intuitive understanding and grasp of the inherent principles and possibilities of the machine bordered on genius. These qualities made him the outstanding and acknowledged leader of the new social class of manufacturers in the movement which for a century made England the leading industrial nation of the world. "We all had our eyes on him," said Sir Robert Peel the Elder, one of the many who paid Arkwright the compliment of imitating his methods of production and management. Although Arkwright did not invent the machines he claimed as his intellectual property, their skilful combination into an efficient system was entirely of his creation. Being the first combination of its kind in history, it deeply influenced the later development of other industries according to the same principle. To his contemporaries he was the personification of a new economic system, and half a century after Arkwright's death Thomas Carlyle, who hated this system with all the fervor of his passionate soul, drew of him the following picture: "Richard Arkwright, it would seem, was not a beautiful man . . . a plain, almost gross, bag-cheeked, pot-bellied Lancashireman, with an air of profound reflection. . . . O reader, what a historical phenomenon was that bag-cheeked, pot-bellied, much enduring, much-inventing barber! French Revolutions were a-brewing, imperial kaisers were impotent without the cotton and cloth of England; and it was this man that had to give England the power of cotton."[13]

[12] Baines, op. cit., p. 226.
[13] Thomas Carlyle, "The Chartists."

THE INFLUENCE OF MACHINERY ON SOCIETY

The power, yes. But also a problem the world has so far tried in vain to solve. The Industrial Revolution did not, of course, create capitalism and the proletariat. Quite to the contrary; their existence was the necessary prerequisite for the appearance and development of the factory system. What the Industrial Revolution did was to provide the conditions favorable for their unchecked growth, and to change them from minor social factors into the dominant forces of our industrial civilization.



THE ROVING FRAME

The roving is drawn from the cans shown in Fig. 1 through the first pair of rollers into the second which revolve more rapidly than the first. The rovings by passing through these two pairs of rollers are drawn out and lengthened. Two of the rovings are then united at the third set of rollers and are drawn out by the fourth, which again revolve more rapidly than the third. In Fig. 2 this fourth set of rollers appears at the top. From these rollers the rovings pass to the spindles below. The roving can used by Arkwright instead of the spindles is shown in Fig. 3.

Already by the beginning of the 19th century industrialism had crystallized into the forms in which it still exists and which later technological and economic developments have modified but have not been able to change intrinsically. Already, then, we find industrial centers with their overcrowded slums, their squalor and ugliness; an uprooted, traditionless industrial proletariat, dependent entirely on the job, helpless and facing starvation without its meager wages; children from the age of six or seven toiling up to fifteen hours a day amid the dust, noise, and heat of unsanitary mills; economic insecurity, the heartbreak of unemployment, and smoldering social discontent. Some of these evils, like child labor, have since been mitigated, but most of them are still a challenge to society.

The outstanding characteristic of the pre-machine age was its remarkable stability. A settled population, fairly evenly distributed over the country and slowly increasing in numbers, industrial labor still in close contact with the soil, a self-sustaining, well-balanced

economy in which the production of foodstuffs and manufactures was keeping step with the gradually rising demand. All these factors tended to stabilize prices, wages, rents, and employment.

The new methods of production made possible by the machine and new processes, like the smelting of iron ore with coke instead of charcoal, thoroughly changed this stable economic order. We have seen how the comparatively unimportant invention of the fly shuttle caused an exorbitant rise of yarn prices, and how the spinning machine, reversing the process by creating an over-supply of yarn, brought about their catastrophic drop. Baines, in his "History of the Cotton Manufacture," published in 1835, estimated that machines enabled one man to produce as much yarn as 250 to 300 hand spinners could have produced, that one man and one boy were able to print as many goods as 100 men and 100 boys could have printed with hand blocks, and "that the 150,000 workers in the spinning mills produce as much yarn as could have been produced by 40,000,000 with the one-thread wheel."

It is easy to visualize the revolutionary sociological changes this increased productivity must have effected and the price exacted for industrial progress expressed in terms of the moral and physical distress of the human beings concerned. At the same time, periods of feverish industrial activity were interrupted every few years by business recessions, permitting consumption to catch up with a production increasing by leaps and bounds, thus causing heavy losses to the manufacturers.

It is no wonder that the first decades of the 19th century were for England a period of social unrest culminating in the revolutionary Chartist movement. Following the introduction of English industrial methods this social unrest spread to the Continent, became a contributing factor to the revolutions which, in 1848, shook nearly all Europe to its foundations, and found its ultimate expression in the communistic doctrines of Karl Marx. A catastrophe was only averted because expanding markets made it possible to absorb the ever-swelling stream of factory-made goods and to find work for the many thousands of workers replaced every year by machines. These markets were providentially provided by the development of the New World, which also offered an outlet for Europe's surplus population; by the opening to western trade of the Far East with its teeming millions; by the construction and mechanization of the means of transportation on land and sea and the stimulus thus given to coal mining and steel making; by the mechanization of industry in general and of agriculture and warfare; and by the satisfaction of wants, frequently artificially stimulated, of a world population increasing at an unprecedented rate.

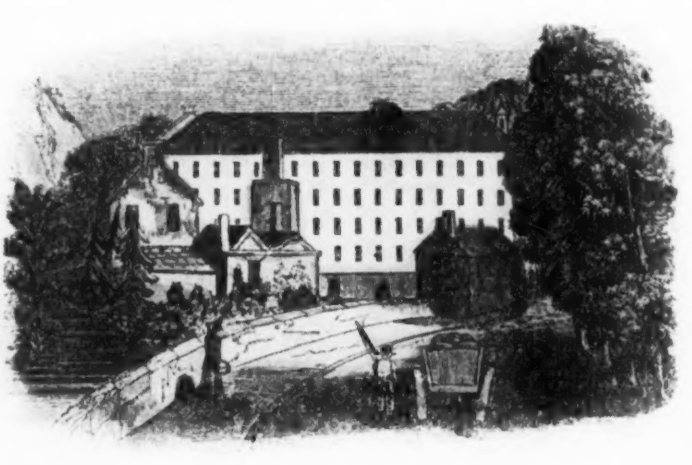
To meet the demands of these expanding markets new inventions, new processes, new industries appeared, creating an apparently insatiable hunger for more and more machines and for more and more raw materials to feed these machines. Like Goethe's sorcerer's apprentice, man had unwittingly set free forces which he did not know how to control and to subjugate to his will.

Nevertheless, up to the beginning of the World War the expansion of industry proceeded in a much less chaotic way than one would be inclined to assume. The curve representing the rate of growth of industrial production for the world as a whole as well as for the principal industrial countries individually shows a steady and more or less uniform rise, although at frequent intervals it is interrupted by irregularities corresponding to business recessions and depressions. The general trend, however, is so pronounced that a prominent economist, Dr. Carl Snyder,[14] comes to the conclusion "that there are in modern industry and technique inherent forces which make for a nearly uniform rate of growth, generation after generation." One is inclined to question this statement which, if true, would contradict the teaching of experience that growth is invariably followed, after a period of stagnation, by decline. From the fact that during the century preceding the World War industry has, under exceptional and non-recurrent conditions, steadily expanded, it does not necessarily follow that it will always continue to do so, and it is equally conceivable that economic forces will retard or even arrest this growth.

WHAT IS THE NEXT PHASE?

For the world as a whole industrial expansion will presumably continue for some time to come, owing to the rapid industrialization of Russia, which might be followed by that of South America and China and, perhaps, of India. The situation is, however, entirely different with regard to the leading industrial countries, the United States, Great Britain, and Germany, which will

(Continued on page 717)



ARKWRIGHT'S MILL AT CROMFORD

[14] Dr. Carl Snyder, "Over-Production and Business Cycles," Proceedings of the Academy of Political Science, June, 1931.

An Appeal for CONSTRUCTIVE THINKING

A Commencement Address Delivered at Haverford College, June, 1932

By HARVEY N. DAVIS[1]

FOUR years ago you entered college from a buoyant and optimistic world. Business was on the crest of the wave, jobs were plentiful, the so-called new economic era was in full swing, and Mr. Hoover was seriously mentioning the possibility of permanently abolishing poverty from the North American continent.

Today you are going out into a discouraged and disillusioned world, a sullen and bitter world, a world dominated, at least for the last few months, by an orgy of economy, and by a wave of hard-boiled disregard of everything not immediately conducive to the grim business of individual survival. It is a terribly soul-contracting and soul-warping world that you will plunge into day-after-tomorrow morning. Don't let it get you; don't let it break your nerve; don't let its callous cynicism undermine your faith and idealism; don't admit for one moment that a breakdown of Western civilization is just around the corner, or that a reasonable sense of security is impossible of attainment under anything like our present economic system, or that a healthy prosperity will never return. Don't assume that a reasonable belief in the value of individual initiative necessarily means every man for himself, without ethics or honor, and the Devil take the hindmost. Whatever may happen to you in the months just ahead, strive earnestly to be masters of your own souls and to stay wholesome, courageous, and generous in all your thinking.

For it is by the thinking of such as you that the future welfare of the country will be determined in the not-far-distant future. It is often said that we are at this moment in a transition period of peculiar significance. Perhaps we are, although I sometimes suspect that it is of the essence of human nature to magnify the importance of yesterday and of tomorrow, without stopping to remember that mankind has already been on the job some forty or fifty thousand years.

Nevertheless, we certainly are at this moment, as always, in a period of transition, and if it has a peculiar significance, that significance lies, I think, in the fact that more people are now thinking, with some intelligence, about the economic and social problems of the day than ever before. It would seem to be, therefore, peculiarly your duty, whatever your vocation may turn out to be, to devote your leisure for some time to come to the earnest study of the now rapidly changing science of economics. Only thus will you be able to have intelligent opinions on the political questions which will concern you, for most modern political problems are fundamentally economic in their nature. And only thus will you be able to play your part in furthering the social advance of your community and of the nation, for many of our most important social problems are merely economic problems viewed through eyes peculiarly sensitive to human implications.

FORMULATE FUNDAMENTAL UNIFYING ECONOMIC PRINCIPLES

In this study, strive above all for perspective, for the large view. This you can do only by continually trying to formulate for yourselves a few fundamental, unifying economic principles, in the light of which you can appraise and interpret the detail of the discussion of the day. Which of the many unifying principles of economics will serve you best will depend largely on your own mental temperament. Choose principles that are sympathetic to your own habits of thought. And do not be disturbed by the certainty that such an approach will tend to give you a one-sided view of an enormously complicated economic world. A clean-cut view, no matter how one-sided, is better than utterly blurred vision even if it sweeps the whole circle of an enveloping fog. You need not worry about warping the judgment of the rest of us by your one-sidedness. It is characteristic of economic speculation that nobody will believe a word you say, no matter how well you have thought it out, unless their own thinking has already led them, perhaps by a quite different path, to a substantially similar conclusion.

Let me try to illustrate this advice by mentioning two economic principles that seem to me significant at this time, and by reviewing some current economic thinking in the light of them. I do this, as I have just intimated, without any expectation that you will accept any of my conclusions, but merely in the hope that I may stimulate you to do some thinking of your own along these or similar lines.

BUSINESS CANNOT PROSPER IN THE ABSENCE OF ADEQUATE PURCHASING POWER

My first economic principle is vividly suggested by the title of Foster and Catchings' book "Business Without a Buyer." It hinges on what has come to be known as the purchasing power of a community, and insists that business cannot prosper in the absence of adequate purchasing

[1] President, Stevens Institute of Technology, Hoboken, N.J. Mem. A.S.M.E.

power. Furthermore, since we have recently waked up to the fact that a very large proportion of the purchasing power of a community reaches its spenders in the form of wages and salaries rather than of profits, that, in other words, purchasing power derives overwhelmingly from a very large number of relatively small incomes and only insignificantly from a very small number of very large incomes, this principle implies that a high wage level is not inimical but rather fundamental to good business. Belief in this principle has swept the country during the last ten years, and was responsible for an unprecedented attempt to keep up wage rates during the early months of this depression. But during the past winter and spring it has perforce been largely ignored in a mad rush for self-preservation.

WAGES AND SALARIES ARE ALSO COST OF PRODUCTION

A second and closely related economic principle is to be found in the writings of the distinguished Englishman, John Maynard Keynes. Briefly and inadequately stated, it is that wages and salaries constitute not only the purchasing power of a nation's business but also its cost of production. If then, no other factor intervenes, the best that business can hope for is to operate without loss; for its own wages cannot supply purchasing power for its goods at a total sales price greater than its cost of production. In fact, if any thrift intervenes in this simple picture, if anybody fails to spend all of his wages, business as a whole must, to that extent, go into the red; hence the hasty conclusion, sometimes attributed to Foster and Catchings, that thrift is a sin.

But, fortunately, other factors do intervene. In particular some people are willing to pay wages directly or indirectly for the fabrication of things that they do not expect to sell, such things as new factories, new machine tools, new public buildings, new roads, and new parks. The production of new capital goods of this sort adds an extra fund of wages and salaries to the purchasing power of the community, and it is this alone that makes it possible for business in general to operate at a profit.

But the mere existence of such a flow of money into consumers' pockets by reason of the making of new capital goods is not, of itself, enough to guarantee profitable business in the face of thrift, unless the rate of expenditure for new capital goods, which puts money into purchasing power, at least equals the rate at which thrift withdraws money from purchasing power. That is, no nation can safely try to save faster than it can find desirable ways of turning its savings into actual capital goods. Of late years the world has been trying to do this very thing, largely because of the vast amount of compulsory saving that has been imposed on it through the efforts of various governments to use heavy taxation to pay off public debts. The inevitable result of this orgy of saving has been a severe depression in business. Conversely, the only way to insure increasingly profitable business, that is, recovery, is to find some justifiable way of paying for new capital goods at a faster rate than the nations are trying to save.

I realize that the account I have given of this second economic principle is sketchy and unconvincing; to become properly acquainted with it you must turn to Keynes's ponderous but most illuminating two-volume "Treatise on Money." I realize, also, that both of the economic principles that I have selected for your attention are in the relatively narrow field of monetary theory. What I am giving you is, indeed, a one-sided view of the economic world. In particular, I am ignoring mass psychology, that tremendous inertia factor in the dynamics of business. I am ignoring the rapidly increasing mechanization of industry and the problem of technological unemployment. I am ignoring the problems of unemployment insurance and the re-education of the unemployed. I am ignoring the possibility of planning production on a national scale. All these and many other important parts of the picture I must leave to other equally one-sided persons, each with a different bias from mine. I can only say that, in my own present thinking, the group of problems that involve monetary theory seem particularly fundamental and significant. Ours is so far from a barter economy that it can be properly understood only through a very careful study of the part that money, and its flow, play in stimulating or hindering the production and distribution of the necessities and luxuries of life. Let us then continue to be frankly one-sided and see what our fundamental principles indicate as to ways of getting out of this depression.

APPLYING OUR FUNDAMENTAL PRINCIPLES TO THE PRESENT CRISIS

In the first place, it is obvious that the prevailing panic of fear grows out of everybody's passionate desire for some measure of security, and that everybody is spending as little, and saving as much, as he possibly can. Under these circumstances it seems foolish for the world to try at this time to collect taxes with which to pay off debts. This is merely an enforced intensification of an already overdone mania of saving. Mr. Hoover's moratorium was thoroughly sound and should be extended.

On the other hand, increasing taxes to balance a budget of current expenditures, either federal or local, has no fundamental significance either way, with respect to the particular phases of the problem that are here under discussion, however desirable it may be for other reasons. Of course most of us would rather spend our own money than have the Government spend it for us, but so long as somebody actually spends it, the effect on the business of the country is precisely the same.

In particular it does no good whatever for the Government to collect taxes with which to build public works. Such a process does not increase the purchasing power of the country; it merely redistributes such purchasing power as already exists.

INCREASING THE RATE OF EXPENDITURE FOR NEW CAPITAL GOODS

And in the second place, it is obvious that we must find some way of largely increasing our rate of expenditure for new capital goods.

Now capital goods are of two kinds which may be called economic capital goods and social capital goods. Economic capital goods are such things as new factories and new production machines which are invested in because of some one's belief that they will pay. If some one would invent something that would justify building up a great new industry, comparable, say, to the automobile industry, our problems would be temporarily solved. But, as the "Russian Primer" has so cleverly explained, a superfluous hat factory or two at this time might wreck not only the builders thereof but many others as well. The trouble with economic capital goods is that the rate at which a community can safely invest in them is controlled by economic forces quite unrelated to the needs of a time of depression. If then we are to do anything about this depression, it must be through social capital goods, that is, through capital goods that are expected to yield a social rather than an economic return. Social capital goods are such things as roads, bridges, water and sewerage works, parks, public buildings, school and college buildings, hospitals, churches, and better housing both for the well-to-do and for the slums. To largely increase the rate at which such things are being built is the only sure way of combating this depression, and it is therefore with keen regret that many of us have witnessed the recent considerable reduction of Federal activity in this direction.

But please remember that, to be effective, such projects cannot be financed by current taxation. The expenditures on them must not displace but must supplement the ordinary expenditures of our daily lives. These things must somehow be built on credit, and at the same time the credit that builds them must be kept good.

ENGINEERS SHOULD HAVE HAD A PLAN FOR THIS EMERGENCY

The only answer seems to be a Federal bond issue. I realize that the floating of such a bond issue without seriously affecting the whole present structure of Federal credit is a delicate and difficult job. Nevertheless I believe it should be undertaken. I believe also that the engineers of the country, both private and public, have been remiss in not having ready for this emergency adequate plans for the spending of the vast sums that should at this moment be pouring into these public and quasi-public works. The preparation of such plans is the most significant contribution that can be made to national preparedness for the next depression ahead. But even though we are at this moment unprepared on the technical side, I believe that we should have a bond issue for public and quasi-public works, that the unemployed engineers of the country should be at once mobilized, at relief wages, to supervise its expenditure, and that the labor involved should also be paid for at relief wages, well below the normal market rate, so that the program will be self-terminating through the voluntary withdrawal of the participants as soon as they can find normal jobs. Only by adopting some such program can I see any possibility of avoiding a dole in its worst form.

COLONEL RORTY'S PROPOSAL

An alternative plan for the expenditure of at least a part of this bond issue, suggested by Colonel Rorty, and recently published as a special supplement of the *Harvard Business School Review*, deserves more attention than it apparently is receiving. Colonel Rorty proposed that the Government pyramid the proceeds of its bond issue by allocating a predetermined number of millions each month as bonuses for the construction of new capital goods by private initiative on a competitive basis. Under this plan any private enterprise willing to undertake the rebuilding or rehabilitation of existing plant or the building of new plant, or any group of citizens willing to build a university building, a park, a toll road, or any other bit of capital goods, would submit a bid offering to spend so and so much money in such and such a way, provided that the fund would provide such and such a percentage of the total. Each month the Federal administrators of the fund, presumably working through committees attached to the various Federal Reserve Banks, would award contracts to the lowest bidders in each district up to the predetermined amount of the bonuses available in that district. For the first few months fairly heavy bonuses might be required, but as the tide turned the pyramiding factor would rapidly increase. Obviously the original law should include provision for the automatic self-termination of the plan as business activity approaches its normal level. A somewhat similar plan for encouraging capital expenditures by local governmental units was tried by the State of New Jersey last winter but it was not very successful largely because of its lack of the flexibility which Colonel Rorty has so well worked out. I am inclined to think that Colonel Rorty's plan should be used in the expenditure of at least a part of any Federal bond issue.

There remains the problem of how to pay off such a bond issue. In so far as self-supporting or quasi-self-supporting public works are concerned, the problem solves itself. If a toll road or a toll bridge can pay its own interest and sinking-fund charges, an issue of appropriate long-term bonds is indicated. The same is true in the case of some public roads whose present maintenance charges would carry the fixed charges of improving them.

The rest of the issue should be short-term bonds so planned as to mature during the next period of prosperity, perhaps between 1935 and 1940. The extra taxation then required to retire them would not only be more bearable than now, but might happily mitigate the excessive prosperity which we are likely to experience again. In view of the fact that we actually did pay off 4.7 billions of our public debt in the five years from 1923 to 1928, it would seem as if we might do something similar again.

A TAX ON INCREMENT OF MARKET VALUE OF SECURITIES

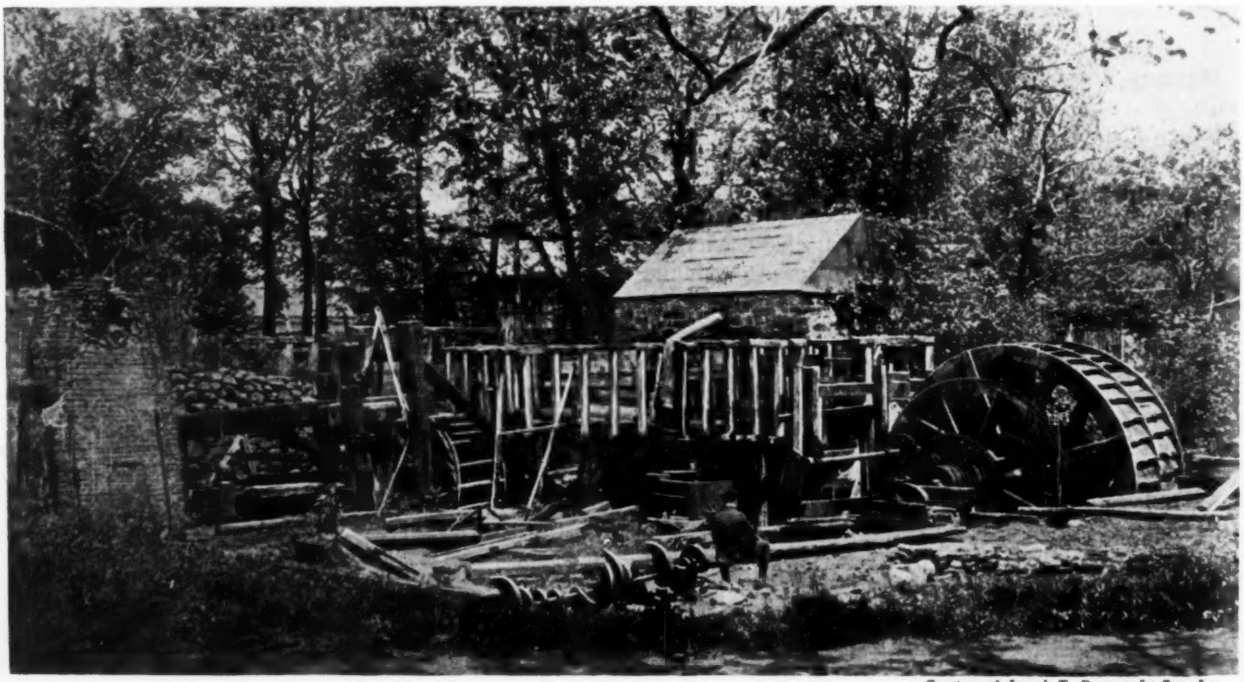
Moreover there are two other possibilities to be considered. The first was recently suggested by Dr. H. C. Dickinson, of Washington. He points out that the present market value of the stocks and bonds listed on the

various exchanges is less by something like a hundred billions than industrial earnings in normal times would justify, and that less than five per cent of the increment in market value that will follow the turning of the tide would pay for the bond issue that would be needed to make the tide turn. Such a tax might be thought of as a direct levy against benefits obviously and directly conferred, and I, for one, would gladly give up one-twentieth of any increment in value that governmental action could produce in the little block of securities that I am, at the moment, trying to hold on to through thick and thin. I would, however, suggest that the last boom taught us the unwisdom of hampering the liquidity of the market by levying such a tax in the form of an income tax on profits realized by sale. The tax should be on increment in market value, without regard to whether an individual sells or not. It should be levied at fairly frequent intervals, say, quarterly or semi-annually. The computation of it should be based, not on market values on a given day, but on average market values over the whole of each levy period as compared with those over the preceding period. And the tax should somehow be collected at the source as a lien against dividends or equity values. Such a tax would automatically disappear at the crest of the next boom, and might be effective in helping to hold down the height of that crest. I realize the tremendous practical difficulties involved in working out any such proposal, but, nevertheless, the plan seems to me to be well worth careful study.

DISCOURAGE NEW CAPITAL EXPENDITURES DURING A BOOM

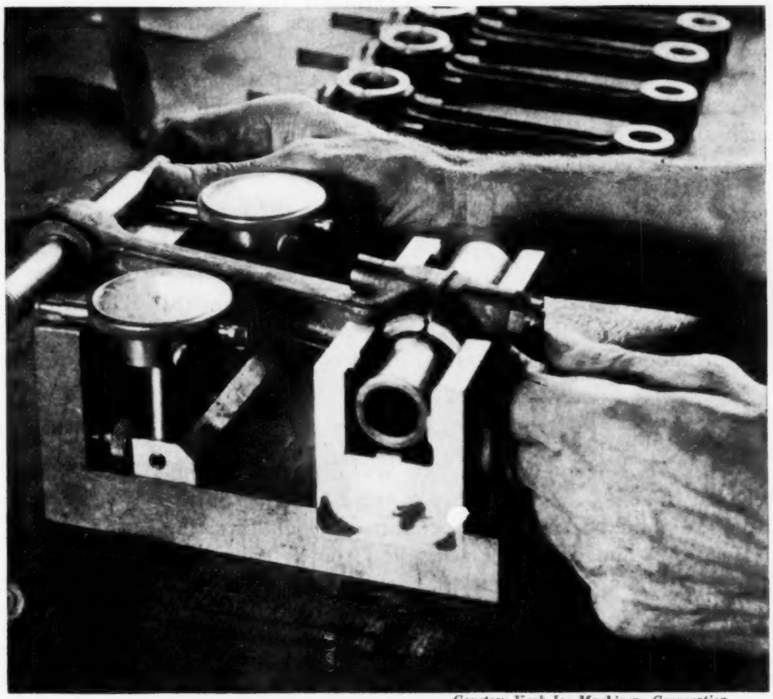
My last proposal for paying off such a bond issue is so obvious a corollary of Colonel Rorty's plan that I was surprised not to find it mentioned in his paper. If it is in the public interest to encourage new capital expenditures now, it will be equally in the public interest to discourage them during the next boom. If it would pay to give bonuses now, it would pay to levy penalties then. Could we not at least partly finance our recovery bonds by a progressively heavy tax on the new stock and bonds that will be issued in such profusion after business reaches normal levels again? The rate should be proportional to the amount by which a Federal or regional index of business activity exceeds a neutral zone around what statisticians would define as normal business. With penalties on capital expenditures when business is superactive, and bonuses when business is superdull, we might hope for some measure of automatic control of the gyrations of the business cycle. Engineers have long since discovered that when an old automobile takes to "shimmying," a comparatively small force applied at the right place in the right way will completely control the unpleasant oscillation. Our task at the present moment is to get the car of business out of the ditch, but the task of the not-far-distant future will be to find and apply the small controlling force that will hold it steady thereafter.

And so I end these musings of an amateur economist. They have, of course, barely scratched the surface of some tremendously important problems. My hope is not that I have persuaded you of anything, but that I have irritated you to the point of thinking some of these things out for yourselves. Try to do that thinking intelligently, intensely and vividly, for on the clearness of the thinking of such young men as you are hangs the future of our civilization.



Courtesy of Joseph T. Ryerson & Son, Inc.

REMAINS OF OLD RYERSON FORGE, NEAR BLOOMINGDALE, N. J.



Courtesy York Ice Machinery Corporation

INCREASED PRECISION IN MANUFACTURE DEMANDS INCREASED PRECISION IN THE DEFINITION OF FUNDAMENTAL UNITS OF MEASUREMENT

DEFINITION OF THE INCH

By H. W. BEARCE[1]

THE development of mass-production methods and close control of dimensions to insure interchangeability of parts has made it necessary for industry to measure the dimensions of many products with a degree of accuracy which would, until recently, have been considered quite impracticable. The need for accuracy in measurements obviously carries with it the need of correspondingly precise definition of the units in which the results are stated. Consequently discrepancies between units which would have been of merely academic interest a few years ago are now of immediate and practical importance to industry. This fact has given new importance to the old question of the relation between the yard and inch of Great Britain and the corresponding units used in the United States, as well as the relation of these units to the meter and millimeter.

For nearly all industrial and commercial purposes the U. S. inch and the British inch may be regarded as equal, although they are now derived from different sources, and although their basic definitions differ. It is only when we are concerned with length measurements of high precision, such as the measurement or comparison of precision end-standards or line-standards, that any difficulty whatever is encountered through lack of exact agreement.

Manufacturers of precision limit gages are regularly working to an accuracy of a few hundred-thousandths of an inch, while manufacturers of precision gage blocks are attaining an accuracy of one or two millionths of an inch per inch of length. Obviously in work of this character, uncertainty or indefiniteness to the extent of the difference between the U. S. inch and the British inch (about 1 part in 363,000) cannot be tolerated.

Furthermore, certain precision measurements in industry and in science are made in terms of the inch, others in terms of the millimeter, still others in terms of standard wave lengths of light. It is highly important that measurements made in terms of one unit be readily and precisely convertible to either of the other units.

Several years ago this problem was discussed by the present author[2] and a solution which seemed practicable was proposed. Since that time considerable progress has been made toward the acceptance of a consistent system of length measurements throughout the world. While there are still differences of opinion with regard to the proper theoretical basis for such measurements,

[1] Co-chief, Division of Weights and Measures, United States Bureau of Standards, Washington, D. C.; Secretary, National Screw Thread Commission.

[2] H. W. Bearce, "A Fundamental Basis for Measurements of Length," B. S. Sci. Papers, vol. 21, p. 395, 1926-7 (S 535).

some recent developments indicate that on all points which are important for practical purposes a general agreement could easily be reached. The purpose of the present paper is to point out the possibility of reaching such an agreement without requiring any great changes in previous conceptions.

RECENT PROPOSALS FOR DEFINING THE INCH

A special committee organized under the procedure of the American Standards Association has now pending before it a proposal to adopt as an American standard for industrial use the factor 25.4 for converting inches to millimeters. This committee has recommended that a conference of interested organizations be called to consider the proposal.

The suggestion of using the simple ratio mentioned is, of course, not new. Its adoption was definitely recommended in 1926 by a conference of representatives of the standardizing bodies of 18 countries, including the American Standards Association and the British Engineering Standards Association. It is, in fact, already widely used both in making computations and in designing mechanical devices for cutting screw threads, ruling scales, and carrying out other operations where conversion between inches and millimeters is involved. The mechanical advantages of this simple ratio were discussed in Bureau of Standards Scientific Paper 535,[2] where it was also stated that official acceptance of this relation would serve to harmonize the theoretical relation with necessary mechanical practice. Adopting a ratio between units does not, however, fix their values until one of the two has been independently defined.

Another proposal recently published suggests the possibility that all concerned with precise length measurements in this country might agree upon a basic definition which would have a very good chance of general acceptance throughout the world. The late Luther D. Burlingame, in a paper presented to the American Institute of Weights and Measures in December, 1931, coupled with the acceptance of the conversion factor 25.4 the further proposal that the yard be defined as 1,420,212 wave lengths of red cadmium light. This would make the inch equal to $39{,}450^1/_3$ such wave lengths. The principle involved in this proposal is entirely in accord with the most modern scientific thought. With a very slight change in the specific number of wave lengths proposed by Mr. Burlingame the complete proposal would be acceptable to scientific circles. It would then give a basis for a restatement of the legal definition of the yard (and inch) which would remove all discrepancies between legal, scientific, and industrial values for the United States inch. It would also go more than half-way toward reconciling the present difference between the legal values of the inch as prescribed in the United States and in Great Britain.

The step necessary to obtain this fortunate result would be to define the yard as 0.9144 meter, which is equivalent to 1,420,213.28 wave lengths of red cadmium light. This would make the inch 39,450.369 wave lengths, instead of 39,450.333 as proposed by Mr. Burlingame.

It will be evident that for industrial purposes the difference of 0.036 wave length of light to the inch is not very serious. On the other hand a difference of this magnitude is not negligible for spectroscopic work and other optical and interference measurements. The value of the meter expressed in light waves has been established to such a precision that a change in it in this proportion cannot be considered. The International Astronomical Union has for twenty-five years used the value 1 meter equals 1,553,164.13 red cadmium wave lengths. This value is believed to be accurate to one part in ten million. Furthermore, this value was at least provisionally recognized by the Seventh General Conference on Weights and Measures in 1927 as a secondary definition of the meter. This definition has already found wide use in the manufacture and testing of precision gage blocks, and in the ruling of line standards of high precision. The suggested modification of Mr. Burlingame's proposal is therefore necessary in order to make the ratio 25.4 to 1 represent the precise relation between the revised value for the inch and the universally accepted value for the millimeter.

PRESENT BASIS OF THE U. S. INCH

The proposed conversion factor (25.4) is not precisely in accord with the present legal basis for the inch in this country. The Act of 1866 provides that the meter shall be considered as the equivalent of 39.37 inches. It is doubtful whether this was intended to establish a precise value beyond the number of figures given, but if one so interprets it, the number of millimeters to the inch is 25.40005 (approximately). Since 1893 the actual U. S. yard and inch have been based upon the International Meter through the use of these conversion factors established by the law of 1866. The national standard is Meter No. 27; it has twice been recompared with the international standards, and the relative lengths have been found to remain constant within the limits of error of the most precise comparisons. The units of length derived in this way have undoubtedly been maintained with a higher degree of accuracy and constancy than would have been possible by the use of any other standard available.

Since the Bureau of Standards assumed responsibility for the maintenance and promulgation of units in 1901, it has been considered best to adhere to the basis which had been established by the Weights and Measures Office of the Coast and Geodetic Survey in 1893. The inch as used by the Bureau is therefore not 25.4 millimeters, but 25.40005. In other words, the present U. S. inch is larger by 2 parts in a million than the value which it is proposed to adopt as an American industrial standard. It is equal to 39,450.448 wave lengths of the red radiation from cadmium instead of 39,450.369. Gage blocks are calibrated on this basis; line standards are graduated and calibrated on the same basis. Any change from that basis will mean a change in the United States inch. Nevertheless this change is advocated in

the belief that it would be advantageous for industrial purposes, while also holding out the hope of ultimate agreement with Great Britain so that the "inch" would have an unambiguous value. The simplest legal basis for the precise values desired would be to define the yard as equal to 0.9144 meter, exactly, instead of specifying 39.37 inches as the equivalent of the meter.

RELATION OF THE U. S. INCH TO BRITISH INCH

Since 1855 the British yard has been defined as the length, at 62 F, of a certain bronze bar made in 1845, and the inch as $^1/_{36}$ of the yard as so defined.

Since 1898 the relation between the British yard and the International Meter has been officially expressed by the following equation:

$$\frac{1 \text{ British yard}}{1 \text{ meter}} = \frac{3600}{3937.0113}$$

The British inch derived from this relation is 25.39998 millimeters (approx.).

From the above it is seen that the U. S. inch and the British inch differ by 0.00007 millimeter, or 0.0000028 inch, the U. S. inch being longer than the British inch by that amount.

Comparisons of the British Imperial Standard Yard with other standards over a period of many years have shown an apparent shortening of this standard, as compared with the International Meter. Some years ago the ratio was reported[3] as 3600/3937.0131, and more recently,[4] as 3600/3937.0147. This latest ratio gives to the British inch a length of 25.39996 mm, thereby increasing the difference between the U. S. and British inches to 0.00009 mm or about 0.0000036 in. The official relation of the British inch to the millimeter, however, has not been changed from that adopted in 1898.

STANDARD TEMPERATURE OF REFERENCE

Another practical difficulty which has stood in the way of complete agreement between measurements made in terms of the U. S. inch and those made in terms of the British inch, and which far outweighed that above referred to, was the fact that in the United States precision measurements of gages, machine parts, etc. were reduced to the basis of 68 F while similar measurements in Great Britain were reduced to the basis of 62 F.

Obviously if parts made in the United States had their dimensions correct at 68 F and similar parts made in Great Britain had their dimensions correct at 62 F, they would not interchange and fit properly, even though the basic definitions of the inch were identical. Parts that were correct at 62 F would be too large to interchange with similar parts that were correct at 68 F.

This difficulty has now been overcome and industrial standards, gages, etc., in both Great Britain and the United States are intended to have their nominal dimensions at 68 F. This important step having been taken by Great Britain, there is perhaps reason to hope that the two countries may also come to an agreement as to the exact definition of an inch and a yard that will be mutually satisfactory.

RECOMMENDED PROCEDURE

It would therefore seem wise to proceed along the following lines:

1 Accept the meter as being represented by 1,553,164.13 wave lengths of cadmium light, under standard conditions.

2 Define the yard as 0.9144 meter (or the inch as 25.4 millimeters).

3 Derive the number of wave lengths in the yard by multiplying the number contained in 1 meter by 0.9144.

4 Derive the number of wave lengths in the inch by dividing the number contained in the yard by 36.

The inch so derived would differ so little from those now in use in the United States and in Great Britain that the change would be detectable only in the most precise measurements. The U. S. inch would thereby be shortened from 25.40005 mm to 25.4 mm (exactly), and the British inch would be lengthened from 25.39998 mm (the official value), or from 25.39996 mm (the more precise present value) to 25.4 mm (exactly). It is seen that the proposed value of 25.4 mm is almost exactly half way between the present U. S. value and the present most precise British value. Could a happier solution be conceived?

So slight a change in the interest of international agreement should not shock the conscience of either country. Great Britain has already accepted 68 F as the temperature at which gages, machine parts, and industrial standards of length shall be correct, and if in addition both Great Britain and the United States adopt the above relation (1 yard = 0.9144 meter), the two great English-speaking countries will be on the same basis, and a very important step toward international standardization will have been taken.

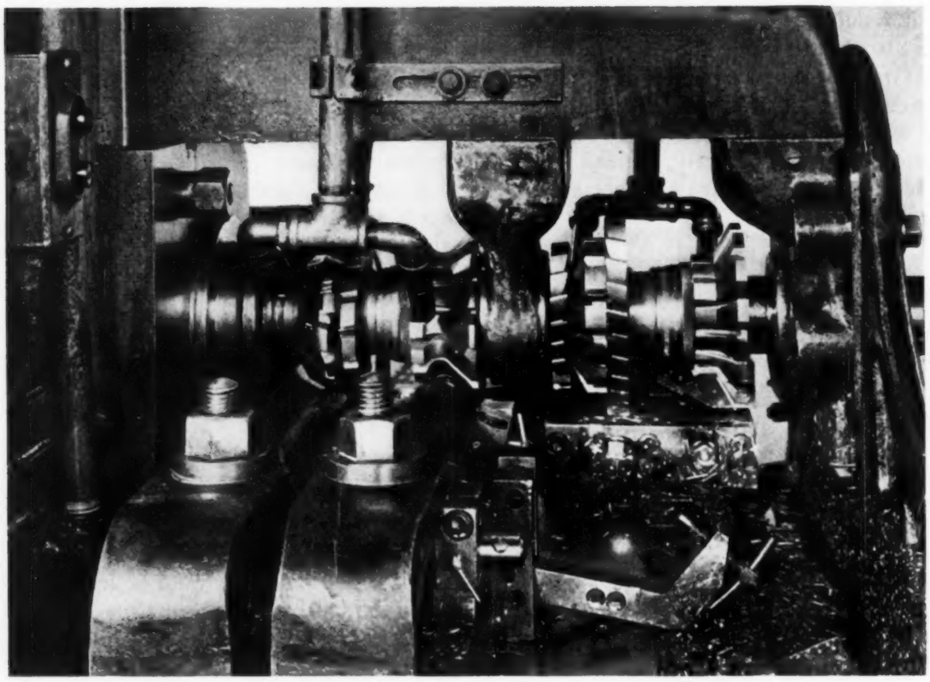
CONCLUSION

In making the above proposals the desirability of obtaining agreement among the English-speaking nations has been emphasized. There is, however, no reason to delay action in the United States pending the establishment of such an agreement. The United States may well adopt the plan proposed in the expectation that its reasonableness and convenience will eventually bring about its acceptance elsewhere.

On the other hand, it would be rather unfortunate to establish a new value for the ratio of the inch to the millimeter without realizing that this involves a very small change in the inch (2 parts in 1,000,000). The proposal to establish the value 1 inch equals 25.4 millimeters as standard industrial practice should be approved. At the same time, however, steps should be taken to change the present legal equivalents accordingly.

Whether precise definitions in terms of wave lengths should be written into the statutes is doubtful. It would at least be wiser to await more definite international ratification of the numerical values before this is done.

[3] Glazebrook's Dictionary of Applied Physics, vol. 3, p. 593.
[4] Phil. Trans. Roy. Soc., vol. 227, p. 281.



A MILLING MACHINE SET-UP FOR CLIMB MILLING

CLIMB MILLING

For Faster Cutting, Greater Accuracy, and Longer Tool Life

By A. C. FULTON[1]

CLIMB milling is not an essentially new development in milling practice. For several years machine-tool men have appreciated its advantages when applied to milling where great accuracy is desired. If, for instance, a long, narrow keyway is being milled in a shaft by conventional up milling, the cut which has been made is inclined to guide the cutter and cause it to run off from the true line of table travel. However, if this same keyway is being milled by the climb method, the direction of the cutter is reversed, and it starts removing metal from outside the cut, and in cutting down into it relieves the directing influence which the cut would otherwise tend to exert upon the milling cutter. So while climb milling should not be regarded as a fundamentally new practice, its accuracy has caused it to be applied for some time past to the manufacture of cutters and to toolroom work where extreme accuracy is important. Its introduction to regular shop productive work, however, has been of recent date, but its ability to remove metal faster, to hold work more accurately, and to increase cutter life is obtaining for it a position of paramount importance in the machine-tool industry.

The reasons for the improved cutting conditions resulting from climb cutting are very simple. Since the cutting edge enters the work at the thick end of the chip, the strain is greatest at the beginning of the cut and decreases to zero at the finish. In the conventional method of milling against the feed, the cutting edge approaches the work from a zero thickness and strain and builds up to maximum. This actually means that the cutting edge drags and rubs the machined surface until the pressure built up is great enough to start cutting. This rubbing or dragging of the cutting edge preceding every cut actually causes more wear than the cut itself, so when this action is so largely eliminated as it is in climb cutting, the life of the cutter is proportionately lengthened. Further, in the conventional up cutting the heat developed is greatest at the finish of the cut and causes the adhesion of the chip

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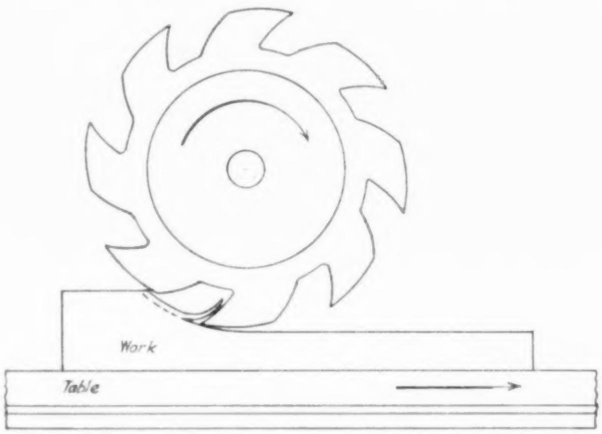
Presented at a meeting of the Philadelphia Section, Philadelphia, Pa., of The American Society of Mechanical Engineers, Jan. 26, 1932. Abridged.

to the cutter. The chips therefore either pile up ahead of the cutter or are carried back on the cutting edge into the succeeding cut. Here again climb milling avoids this undesirable condition, in that the chips are discharged behind the cutter and as the heat developed is least at the finish of the cut, the possibilities of the adhesion of the chip to the cutter are greatly reduced.

Climb cutting produces a dull finish on the surface, which indicates free cutting, and with a true rotation of the cutter and arbor there is a smooth finish and absence of feed marks at feeds which would show considerable feed mark with the usual practice of milling against the feed. This reference is to work using surface



CUTTER ARRANGED FOR CONVENTIONAL MILLING

The rotation of the cutter is clockwise and the direction of travel of the table is from left to right as indicated. The tooth of the cutter, in this case, is under a minimum pressure at the beginning of the cut and builds up to maximum at the finish. There is a rubbing action between the tooth and the work until the pressure built up is great enough for cutting to begin; this causes excessive wear on the cutting edge. The chips are discharged ahead of the cutter.

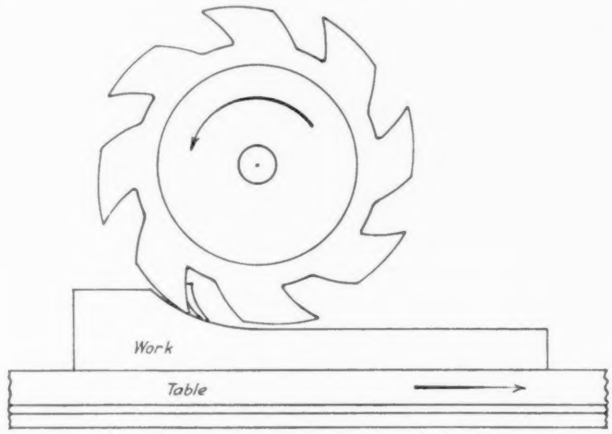
milling cutters, such as slab mills and formed cutters on work free from a hard surface scale. It is obvious that climb milling is not so readily applicable to work having a hard scale, for then, rather than cutting up through the scale, each cut would have to be started down through it and cause excessive wear on the cutting edge.

The ideal cutting conditions in a milling machine should parallel as nearly as possible those of a broach. In broaching, the cutting tool itself controls the path of travel, the rigidity to the cutting edge, and the feed or thickness of chip. In the milling art the elements which parallel these conditions are:

1 Powerful true cutter rotation
2 Rigidity
3 A true plane of table travel
4 Positive locked feed.

The ability to perform economically, secure maximum life to the cutting edge, and do accurate work is all related to the measure in which these elements are provided.

Powerful true cutter rotation is necessary for three reasons, namely, for power, for milling where there is an unbalanced end or side thrust on the cutters and arbor, and for interrupted or broken cuts where the area of surface being machined varies. Without a rotation which is both true and powerful, the cutter, while milling work developing unbalanced thrusts or having interrupted surfaces, will tend to spring from the work with the result that inaccuracies will develop that will preclude heavy cutting. To obtain satisfactory cutter rotation, it is necessary that adequate drive mechanisms be provided, that there be proper rigidity in the head and arbor support, and that the arbor itself have generous proportions. The arbor support should have



CUTTER ARRANGED FOR CLIMB MILLING

The rotation of the cutter is counter-clockwise and the travel of the table is from left to right as indicated. As can be seen in the sketch, the tooth of the cutter starts the cut where the thickness of the chip is the greatest and the pressure on the cutter decreases to zero at the conclusion of the cut. The chips are discharged behind the cutter.

taper bushings so that as wear develops, compensation can be made for it.

A true plane of travel to the table is one of the most important conditions necessary for accurate milling. Dovetails have been used in the conventional design of milling-machine slides. It has been the general experience that this type of slide provides only a temporary plane of true travel for the reason that the dovetails quickly wear irregular and to a bowed shape with respect to the pitch line. This occurs in both the bed slide and the table. With both members made of cast iron and subjected to the usual exposure to cutting compounds and other destructive elements, these slides wear rapidly and the corrective means involve replaning and rescraping. A "V" construction such as is used in lathes and planers is especially well adapted to climb milling, and even more so where the cutting is interrupted or such as to create side pressure. Here, because of the down cutting, the wear on the table ways is greater than in up cutting, and to secure and retain a true plane of table travel, it is almost essential to use a "V" construction with hardened members in the table ways.

An automatic backlash remover is necessary for climb cutting, but is an addition which could be beneficially

made to practically all milling work, since it is an added assurance of positive locked feed. The application of a positive locking device creates greater wear on the nut and screw. To offset this, the screw should be designed to allow for a generous bearing surface on both sides of the thread.

While climb milling can be applied to almost any type of milling machine, it is not recommended for the knee-type machine where the object is heavy productive work. The knee-type machine, while having the advantages of adaptability and universality, is not rigid enough to stand up under the heavy cutting that is possible through climb milling. A fixed-bed machine is essential to the securing of the maximum cutting that can be obtained by a wise application of the climb principle.

The problem of applying climb cutting to long-run productive jobs is very simple, since this class of work makes possible a thorough study of conditions and fixtures to suit the need, and full advantage can be taken of the greater cutting possibilities afforded by the climb method. There are many advantages to be found with an alternating milling cycle, where two fixtures are placed on the table in direct alignment with one another and with a single cutter direction, milling with the feed in one fixture and against it in the other. The application of climb milling to short-run work is also highly productive, providing that the character of the work is such that in using a fixed-bed machine to get the greatest cutting, the comparative inflexibility of the machine does not result in too large an increase in set-up time.

There are several very definite advantages to be derived from the climb-milling principle. First of all there is the economy resulting from greater cutter life. Both theory and practice prove that climb cutting, with the exception of milling through heavy scale, gives more pieces per grind of the cutter than does the conventional up milling. This being true, there is greater life to the cutter, for there is less wear and fewer grinds per machined piece. It follows that with fewer grinds there are fewer tear downs and set-ups required as a result of dull cutters.

Where great accuracy and good finish are desired, climb milling is far superior to up milling, for the cut cannot determine the course of the cutter, it being determined solely by the rigidity of the machine, the rotation of the cutter, and the travel of the table. The finish secured is better because of the absence of the peening action of the cutting edge on the machined surface while the cutting edge is building up the chip.

Much heavier cutting is possible with climb milling because the resultant pressure of the cutter is downward, eliminating heavy clamping and vibration. In up milling it is necessary to have rigid clamping to keep the fixture from moving or lifting. This materially simplifies the design of fixtures.

I do not wish to leave the impression that I consider climb milling to be a panacea for all milling problems. In general, it will result in considerably longer life for the cutting edge because of the absence of vibration or chatter. On an accurate machine milling certain types of work it will produce greater accuracy than is possible with conventional cutting. In many cases it will simplify the design of fixtures as the necessity for vertical clamping of the work and of the fixture is overcome. Lastly, it will make possible much heavier cutting than can be obtained by the up-cutting method. This last advantage, however, cannot, in the majority of cases, be fully realized without the purchase of new equipment. The heaviest cut which it is possible to take is limited by the strength or rigidity of the weakest element taking part in the cut. There is no advantage in building massive fixtures and powerful cutters if the head and arbor, or the table, of the machine are not proportionately strong. To secure the greatest cutting possibilities which are revealed in climb cutting, it is almost essential that recourse be had to a fixed-bed type of machine. The knee-type machine in common usage has the advantages of adaptability and universality of application, but in general lacks the strength and rigidity that are indispensable in climb cutting, where the objective is heavy cutting without the sacrifice of accuracy.

Strength of Metals at High Temperatures

THE Department of Scientific and Industrial Research has just issued a report dealing with the results of an examination of the mechanical properties of six heat-treated steels, namely, 0.5 per cent carbon steel, 3 per cent nickel steel, nickel-chromium steel, chrome-vanadium steel, stainless steel and staybrite, and also phosphor bronze, duralumin, and 60:40 brass.

In the main, the short-time tensile and creep properties have been determined at 300 to 600 C for the steels, and at 150 to 500 C for the non-ferrous metals. From the creep tests the stress-temperature relations for rates of creep down to 10^{-5} in. per inch per day have been obtained. Notched-bar impact tests have been carried out between 0 and 700 C on the carbon and nickel steels.

Results obtained for the tensile and creep properties of the materials provide information permitting the estimation of suitable working stresses at different temperatures.

It is shown that the nickel steel is no better than the carbon steel at 400 C and above, the nickel-chromium steel is definitely inferior to the other low-alloy steels, and the chrome-vanadium steel is inferior to the nickel steel and carbon steel at 500 C. Stainless steel has similar creep characteristics, but is definitely superior to the low-alloy steels.

Staybrite withstands relatively high stresses for long periods with little creep, but owing to its low limit of proportionality, considerable initial permanent deformation occurs under these stresses.

Of the three non-ferrous metals, phosphor-bronze is the superior, and both phosphor-bronze and duralumin are much superior to 60:40 brass at 250 C and above.—*The Engineer* (London), July 1, 1932, p. 18.

HYDROELECTRIC DEVELOPMENTS

and the Correlation of HYDRO AND STEAM POWER[1]

By F. A. ALLNER[2]

DURING the past two years hydroelectric development in the United States has not maintained the same relative place as a source of power that it held previous to 1929. The chief factors which have contributed to this gradual shifting of its relative importance are the materially reduced fuel costs of steam-electric plants, the drought which prevailed over large areas of the United States during 1930 and 1931, and the uncertainties of governmental policy, both state and federal. Although the capacity value of hydro plants, i.e., the cost of procuring equivalent-capacity service by other sources of power, has not been measurably affected so far by the advance in the art of constructing thermal plants, yet the value of hydro energy, i.e., the cost of producing energy by other means, has been reduced in recent years to the lowest figure ever encountered. This is chiefly due to the prevailing low prices for coal, the advent of natural gas, improvements in thermal economy in steam-electric plants, and the large size of steam units as well as the great total capacity of individual stations.

On the other hand, certain factors of increasing advantage to hydroelectric development have made possible, and hold promise for still greater usefulness of, numerous hydroelectric projects which would not have been considered economically feasible during preceding years, notwithstanding the higher unit value of energy in those years.

Among these factors is the present large size of electric-utility systems in consequence of natural growth as well as of the interconnection of contiguous load areas. Almost without exception, new large-scale hydro developments are made by electric systems which supply their output to metropolitan load centers or to a group of systems covering a regional territory.

The shape of peak of electric-system loads is favorable for utilizing a large installed capacity in hydro plant under minimum water conditions, which allows a large capacity value to be allotted to hydro. Another feature of large utility-system loads until the past year has been the annual increase in peak, which has been of such an amount that the entire capacity of new hydro developments has become usable on the peak within a comparatively short time. On the other hand, the minimum system load is sufficient to absorb a large hydro output when water is plentiful in run-of-river plants. Plants that can be developed beyond the continuous flow capacity at a low incremental cost can produce a large volume of secondary energy.

Factors Affecting Hydroelectric Development—Selection of Turbines—Factors Controlling Choice of Hydro or Steam as Source of Supply—Operating Combined Sources of Supply—High-, Medium-, and Low-Head Storage Plants—Pumped Storage—Dual-Use Capacity Plants.

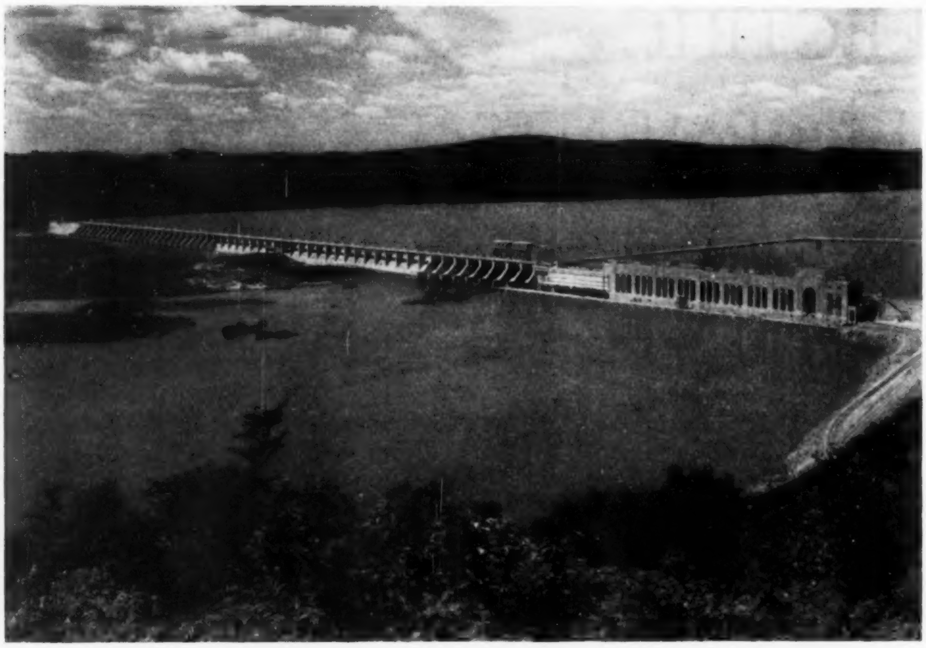
Advance in the art of power transmission has made it possible to transmit large capacities over long distances at reasonable cost, good voltage regulation, and low energy losses. Step-up switching stations at the hydro plants and step-down terminal stations of transmission lines can be developed advantageously as integral parts of interconnection projects, tying together large power systems which formerly functioned as separate units into a regional power system extending over large areas. In this manner a dual function is performed by the hydro transmission and tie-in investment, especially on systems which have adopted 230 kv as standard voltage. The high degree of service reliability of all types of equipment at this voltage has encouraged designing engineers to simplify their system layouts and to rely more on higher mechanical and electrical factors of safety of equipment than on a multiplicity of lines and reserve apparatus, all of which had a tendency to reduce investment cost or increase the service value of the hydro projects.

At the hydro plant proper, a number of factors have contributed toward the lowering of investment cost, aside from the effect which may be ascribed to lower price levels of structures and machinery. With construction plants laid out for low handling cost and rapid progress, and with careful engineering work applied to other temporary structures, flood control, etc., the period of construction has been shortened and substantial amounts are thereby saved which formerly were expended on interest and other carrying charges during construction. Economies in the cost of financing are made possible by the sponsoring or underwriting of major enterprises through existing large utility systems, and few projects are now undertaken for which the market has not been secured in advance at least to the extent necessary to insure the interest on bonded indebtedness with a sizable margin of earnings.

It is possible now to get more capacity out of a given structural space, not only because of increased size of units but also because of higher specific speed of turbine runners and improved design of water passages. Higher speed and improved design

[1] Third section of a paper entitled "Production and Transformation of Electrical Energy in the United States," by Alex. D. Bailey, A. G. Christie, F. A. Allner, and F. C. Hanker, contributed to the International Electrical Conference, Paris, France, June, 1932. The first two sections, by Messrs. Bailey and Christie, were published in the August and September issues of MECHANICAL ENGINEERING.

[2] General Superintendent, Pennsylvania Water & Power Co., Baltimore, Md. Mem. A.S.M.E.



GENERAL VIEW OF SAFE HARBOR POWER DEVELOPMENT ON THE SUSQUEHANNA RIVER

of machinery have lowered the cost of main-turbine and generator equipment. Auxiliary apparatus has been simplified and its cost decreased. No appreciable improvement in best efficiency of runners has been recorded during the past ten years, but high efficiency can now be secured over a wider range of loading, and the overall efficiency of energy conversion for the plant as a whole has been raised noticeably over that of earlier installations. Testing of models is no longer confined to runners and draft tubes, to observations of efficiency, output, and to studies of the cavitation problem, but extends to every phase of the project from headwater intakes down to the lower end of the tailrace channel. As a result of model tests, more economical designs of spillways, pier and apron sections, flood gates, etc. have been developed. Effective steps have been taken at the newer plants to guard against the interference of service that is caused by trash and ice runs.

TURBINES OF RECORD SIZE

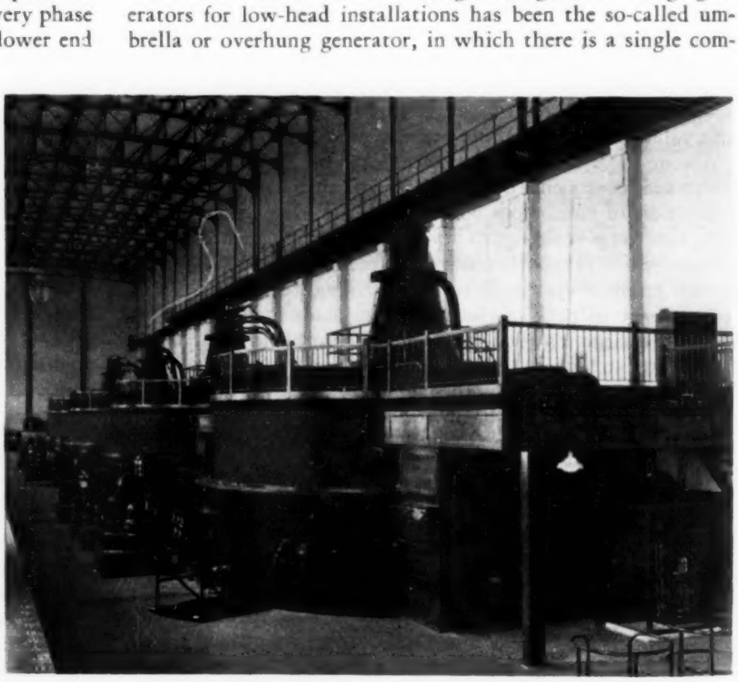
Francis-type turbines are being installed in the Diablo plant in Washington, where two wheels will develop 90,700 hp each under a head of 327 ft. A turbine of 57,000 hp capacity has recently been installed in the Spier Falls, New York, plant, both the turbine and generator approaching record sizes in physical dimensions. The operating speed is 81.8 rpm under a head of 81 ft; the generator stator is 37 ft in diameter, and the diameter of the scroll-case entrance is 26 ft. Three units of 49,000 hp capacity each in the Waterville, N. C., plant are the largest high-head Francis wheels in point of capacity, the operating head being 840 to 750 ft. The low-head (55 ft) plant at Safe Harbor, Pa., contains the largest automatically adjusted propeller turbines in the United States.

SELECTION OF TURBINE TYPES

Francis-type wheels are now designed for a higher specific speed than was customary a few years ago, but the limit to specific speed seems to have been reached. The fixed-blade and then the manually-adjustable-blade propeller wheels were adopted to increase the operating speed, and permitted smaller dimensions and higher efficiencies of electric generators. The part-gate efficiency of the non-adjustable-blade propeller wheel is lower than that of the Francis wheel, and lately there has been an increasing use of the Kaplan turbine, of which the blades are controlled by a speed-responsive governor to give a higher part-gate efficiency than can be obtained with the Francis wheel. The Kaplan turbine with automatically adjustable blades, because of higher part-gate efficiency, produces a greater integrated energy output under variable water-flow conditions than either Francis or fixed-blade propeller wheels. In one recent plant Francis wheels of different sizes were installed for the purpose of maintaining high efficiency under all flows. Storage-type plants allow the Francis wheel to be operated at an efficient gate opening.

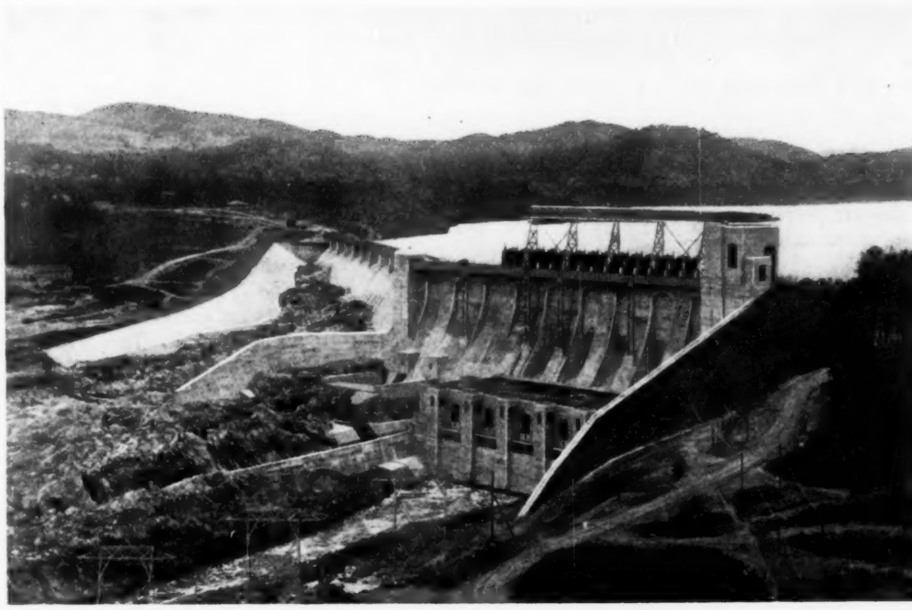
FEATURES OF GENERATOR DESIGN

A recent innovation in the design arrangement of large generators for low-head installations has been the so-called umbrella or overhung generator, in which there is a single com-



GENERATOR ROOM, SAFE HARBOR HYDROELECTRIC PLANT

bination thrust and guide bearing located below the rotor. Its chief advantages are a reduction in overall height and convenient arrangement for ventilation. Another marked change in design of water-wheel generators has been the use of rolled steel plates and fabricated structures instead of the castings formerly employed. This design gives a lighter machine which is adaptable for special ventilating and constructional requirements. Generator cooling by means of a closed water-cooled air-circulating system is a recent development in hydroelectric plants.



FIFTEEN MILE FALLS HYDROELECTRIC PLANT LOCATED ON THE CONNECTICUT RIVER

BUILDING ARRANGEMENT

The generator-room superstructure has been omitted in several recent plants having from one to eight units. The usual arrangement is for one leg of the outdoor gantry crane to travel on the substructure downstream from the turbine or generator casing, and the other end of the crane to rest on the wall of the forebay or electrical bay. Metal housings are provided over each generator. Attachments are sometimes provided on the crane for the direct handling of transformers and headgates. In many of the newer plants, the floor formerly located at the level of the generators has been omitted by mounting the generators on concrete pedestals; this arrangement concentrates the machine auxiliaries on one level and facilitates the layout of governor piping.

PENSTOCK VALVES—AUTOMATIC CONTROL EQUIPMENT

There has been a decided increase in the use of butterfly valves in penstocks ahead of the scroll case, both in large sizes and under high heads. Leakage has been very small, and the valve can also be used for free discharge. Metal or rubber sealing rings are provided around the periphery to obtain water-tightness, particularly valuable for peak-load operation in low flow.

Equipment has been successfully developed for regulating the electric frequency of hydroelectric generators and for controlling the load distribution between units in accordance with plant demand and hydraulic conditions.

GENERATOR ROOM, FIFTEEN MILE FALLS HYDROELECTRIC PLANT

FACTORS CONTROLLING CHOICE OF HYDRO OR STEAM

There are very few electric systems in this country supplied wholly by hydroelectric generation, chiefly because it has been economically advisable and often necessary to provide low-flow reserve generating capacity by means of steam plants located near load centers. There is no generally accepted ratio of hydro to steam capacity for best economic results, but the optimum proportion for any system is determined by the relative investment cost, the fuel costs of steam energy, and the characteristics of system load and water supply. Fundamentally, the benefit derived from the two sources of supply comes from the combination of a low operating energy cost in the case of hydro with a low unit investment cost in the case of steam; but while the total investment to carry the system peak may be larger in a combined system than with steam alone, the excess investment is more than compensated by the low cost of energy derived from hydro. The two sources of power should

be regarded as supplementing rather than competing with each other. The quick-starting characteristics of hydro units, that is, their ability to start from standstill and synchronize with the load in a small fraction of the time required for steam units, provide a high degree of standby readiness for emergencies. Hydro units are also adapted to no-load operation as synchronous condensers for voltage regulation or power-factor correction without consuming much energy or requiring elaborate precautions against overheating or rubbing as in the case of steam units.

OPERATION OF COMBINED SOURCES OF SUPPLY

The best method of operation on a combined hydro and steam system is generally found by scheduling the hydro plants for maximum efficiency in periods of deficient water, and for maximum energy output in periods of plentiful water. Operation is simplified by the presence of hydro storage. Hydro capacity is held available during low flow for instant use in case of emergency at associated steam plants. Hydro always supplies a belt on the system load curve according to water availability such that the largest possible hydro capacity is utilized, thereby operating associated steam plants at improved load factors in periods of deficient water.

HIGH-HEAD STORAGE PLANTS

High-head plants, usually associated with limited water availability, are located in mountainous regions, and must be developed by seasonal storage dams, long tunnels or conduits, and high-pressure penstocks. The total cost of these developments per kilowatt delivered at the load centers is relatively high, and the incremental capacity cost is also high, since considerable duplication or enlargement of water works is required for any increase in installed capacity. Where fuel costs are low, such plants must operate at the highest possible use factor, in addition to contributing their entire capacity to the system load.

An outstanding example of this type of development now in progress is on the Mokelumne River in California, where a gross static head of 5100 ft is being utilized in four plants which will be operated in series with no more than a few hours' to a day's regulating pondage between any of the plants. The drainage area is 356 square miles; the average seasonal stream flow is 818 cfs (300,000 cfs-days per season), varying from a maximum of 1660 to a minimum of 250 cfs. The greatest peak flow through any power house is 650 cfs, and the average is about 550 cfs. Regulation of the run-off is accomplished by storage reservoirs having a volume of 100,000 cfs-days. Five main dams are necessary in addition to those previously constructed; one of the new dams is the largest rock-fill dam in the world, having a height of 328 ft, a crest length of 1300 ft, and a volume of 3,000,000 cu yd. The combined plants will have a peak capacity of 144,000 kw, and will generate about one billion kilowatt-hours in a normal water year, equivalent to a peak use factor of about 80 per cent. Three of the turbine installations will use impulse wheels operating under gross static heads of 1219, 1265, and 2089 ft, and having kilowatt equivalents of 85 to 145 per cu ft of water. Two turbine installations will be Francis-type wheels under gross heads of 245 and 285 ft, with kilowatt equivalents of 15 to 20. Energy from the Mokelumne River plants is supplied to an electric system whose peak load in July, 1930, was 853,300 kw; the peak is expected to have an annual growth of about 50,000 kw.

MEDIUM- AND LOW-HEAD STORAGE PLANTS

In the case of medium- or low-head plants on streams having wide variations in flow, where it is feasible to provide a moderate amount of seasonal storage, the major portion of the cost is in pondage and dams, and generating capacity can be added at a low incremental rate. Some of these projects have created artificial lakes of record size, although the entire volume is not usable for power-house draft. Whereas the usable storage on the Mokelumne River is approximately equal to the yearly run-off in a dry year, but only about one-third of the average run-off, the usable storage on the Osage and Connecticut Rivers constructed for the Bagnell and Fifteen Mile Falls plants, amounts to only about one-sixth and one-fifteenth of the average run-off, respectively. Another distinction is revealed by the ratio of maximum power-house draft to minimum regulated flow; this figure is approximately 2.4 for the Mokelumne River, 10 for the Bagnell plant, and about 11 for the Fifteen Mile Falls plant. This overdevelopment in relation to minimum regulated river flow is justified by the peak-capacity value contributed by the hydro plants to the electric systems of which they are a part. The Bagnell plant, of an initial capacity of 129,000 kw (172,000 kw ultimate) and an average annual output of 425 million kilowatt-hours (150 million minimum and 800 million maximum), supplies a system having additional capacity of 572,000 kw and a yearly load of 1.8 billion kilowatt-hours; the Fifteen Mile Falls plant has a capacity of 150,000 kw in four units and delivers its output of 300 million kilowatt-hours to a system embracing a large part of industrial New England, including the metropolitan district of Boston. The average yearly capacity use factor of the Bagnell plant is about 38 per cent for the initial installation of six of the eight ultimate units; the Fifteen Mile Falls plant has a use factor of about 23 per cent. Other plants are located on the Connecticut River below the Fifteen Mile Falls plant and also receive the benefit of the storage created at the new plant.

LOW-HEAD RUN-OF-RIVER PONDAGE PLANTS

This type of plant involves a large initial outlay for dam and pondage rights, and cannot be justified in capacities below a certain minimum. The power house usually forms part of the dam, and generating capacity can be installed at a low incremental figure. The characteristics of present-day electric systems are such that a major part of the initial capacity necessary for economic justification of run-of-river plants renders firm capacity service in the upper portion of the annual load curve under minimum-flow conditions.

Compared with minimum flow as regulated by the available pondage, these plants have a large excess capacity. For instance, the new Safe Harbor plant on the Susquehanna River in its initial six-unit development has a full-draft flow fourteen times, and in its ultimate twelve-unit development, twenty-eight times the minimum regulated flow; in other words, if the entire ultimate plant capacity were peaked during the minimum-flow period, this peak operation being repeated every day, the plant load factor would be less than 4 per cent. Operation at such a low load factor will probably never be required for any length of time.

The peak operation of this particular plant will also be coordinated with that of two lower plants on the same river. The aggregate steam and hydro capacity installed in the load area served either directly or reached through interconnections from these three plants is in excess of 3,000,000 kw, and even on days of greatest withdrawal of impounded water, a large amount of off-peak steam energy will be available for pumping back the major part of the water into the upper reservoir.

In contrast with the above-mentioned extremely low load factor as calculated theoretically for a day of highest peak demand coinciding with minimum flow, this plant will have an average yearly use factor of approximately 50 per cent because there is sufficient flow during a large part of the year to operate

all units at 100 per cent utilization. During periods of plentiful water, the generating capacity installed at low incremental cost produces a large volume of secondary energy which supports the investment necessary for the first block of capacity. The initial development supplies a metropolitan load and extensive railroad electrification.

The Safe Harbor plant is located on a river whose flow varies from a minimum of 2300 to a peak of 725,000 cfs, with an average flow of 39,000 and a median flow of 23,100 cfs. The drainage area is 26,090 square miles. Six units of 168,000 kw total capacity compose the initial installation, and have a full draft of 48,000 cfs. The dam and power house have a length of about one mile and create a gross head of 55 ft. The usable storage obtained from 15 ft drawdown amounts to 35,000 cfs-days, equal to 1.33 cfs-days per square mile of drainage area. The plant is notable for being the first in the United States to use large-size Kaplan turbines. These wheels have a diameter of 220 in. and develop 42,500 hp at 109.1 rpm.

PUMPED-STORAGE PLANTS

Pumped-storage plants involving specially constructed high- or low-level storage reservoirs do not play so important a part in the power-supply scheme of large systems as they do in continental Europe. Several such projects are under discussion, but only one major installation, a plant built in 1928 on the Rocky River, a small tributary of the Housatonic River, in New England, is actually in service. The plant pumps from the Housatonic River to a reservoir of 68,000 cfs-days usable capacity located on the Rocky River. The average yearly runoff of the Rocky River is 17,000 cfs-days. The pumping equipment consists of two vertical shaft 8100-hp motor-driven pumps, each delivering 250 cfs against a head of 240 ft. These units are the largest high-head centrifugal pumps in this country. For generation when withdrawing water from the reservoir, a separate 33,000-hp vertical-shaft Francis turbine is installed; a single penstock between power plant and reservoir serves for pumping and generation.

While pumping is done mainly by off-peak steam power, the Rocky River plant provides in addition seasonal storage service to other plants located below on the Housatonic River. The installation of the 24,000-kw generating unit in the Rocky River plant and the pumped-storage reservoir actually added 40,000 kw of yearly firm capacity to the electric system served by the plant. The presence of the lower plants also results in an overall conversion efficiency of 79 per cent, but the efficiency of direct recovery by the Rocky River plant alone is only 61 per cent.

DUAL-USE CAPACITY INSTALLATIONS

This novel type of development is functionally related to pumped-storage plants, being based on the principle of converting low-cost off-peak energy into high-value peak capacity and energy. It employs the same unit as a turbine-generator and a motor pump set, without, however, requiring a specially constructed high- or low-level storage reservoir, conduits, or hydraulic control equipment. It is especially adapted to those hydro plants where the increment cost of generating and transmitting capacity is lower than that of equivalent steam capacity, and where a substantial overlapping of heads can be readily arranged. The runoff characteristics should be such that, depending on the efficiency of the conversion cycle, the duration of the low-flow stage, during which conversion of off-peak energy into peak energy takes place, is not too great compared with the duration of the excess-flow period, during which the dual-use equipment produces energy for the system. The above conditions are somewhat interrelated in that in some instances a large saving in investment cost may more than compensate for the extra cost of energy caused by conversion losses during low flow exceeding the gain in output during high flow, notwithstanding the fact that on such a project the low-flow days may greatly outnumber the high-flow days.

The operation of the generator in reverse direction as a motor offers no serious difficulties, but the design of the different types of turbines and hydraulic structures for dual use at synchronous speed and the possibilities of variable-speed electrical and hydraulic equipment have not yet been developed to a point where the "regenerative cycle" can be adopted for more general use. The Safe Harbor plant will be the first low-head development at which this method will be employed.

GENERAL VIEW OF SALT SPRINGS POWER HOUSE, MOKELUMNE RIVER, CALIFORNIA

The Product of the
ENGINEERING COLLEGES

By DONALD B. PRENTICE[1]

WITHIN a year there has been published a carefully edited volume of "Who's Who in Engineering." Quoting from the preface:

The third edition of "Who's Who in Engineering" takes its place among personal reference books with a history of unusually thorough compilation behind it. . . . In accordance with this, the American Engineering Council appointed an Advisory Committee on "Who's Who in Engineering." [Thirteen prominent engineers served on this committee.]

The Advisory Committee voted to include engineers whose experience gave them the following qualifications:

a Engineers of outstanding and acknowledged professional eminence
b Engineers of at least ten years' active practice, at least five years of which have been in responsible charge of important engineering work
c Teachers of engineering subjects in colleges or schools of accepted standing who have taught such subjects for at least ten years, at least five years of which have been in responsible charge of a major engineering course in such college or school. . . .

Questionnaires were mailed to every available list of engineers.

The records revealed by these questionnaires were then tested by the foregoing specifications, and those who passed were included in the volume.

Inasmuch as practically every engineer must have received a questionnaire, omission from "Who's Who in Engineering" must be due to failure to return the personal record or inability to meet the committee's specifications.

"WHO'S WHO IN ENGINEERING" USED AS A BASIS FOR IMPARTIAL CHECK ON COLLEGE GRADUATES IN ENGINEERING

Assuming that inclusion in this volume is one test of success in engineering, we have an impartial check of the products of technical colleges. Certainly inclusion did not depend on college affiliation. If we tabulate, according to their alma maters, those whose biographies claim graduation, we shall have a measure of the contributions to engineering leadership by American colleges of technology. Some chemical engineers, physicists, and geologists are included in "Who's Who in Engineering," and in many instances these men secured their undergraduate training in so-called arts colleges. We shall find, therefore, that the institutions contributing alumni to this collection exceed in number the purely engineering schools, and include, in fact, one college solely for women—Wellesley.

A number of biographies state that more than one college had been attended. Therefore an arbitrary rule was adopted for the study reported in this article, that credit would be given to the college which first gave the engineering training. A graduate of Amherst, for example, who received an engineering degree a few years later at Cornell, was assigned to the second institution. A graduate of Case, on the other hand, who received a second engineering degree at Cornell, was credited to Case. A graduate of Amherst, however, who continued work in geology at Yale for the Ph.D. degree, was listed for Amherst.

In this edition of "Who's Who in Engineering" there are biographies of 8643 graduates of colleges and universities in the United States and Canada. Many graduates of foreign universities are also included, but no attempt was made to catalog them. Many more of the included engineers attended college for one or more years. As a safe rule, and to eliminate personal judgment in the interpretation of biographies, only those were listed in this study who definitely claimed to be alumni, either by stating the degree or the fact. Quite possibly as a result a small number of actual graduates were omitted from this compilation, but the author was unwilling to assume the responsibility for resolving ambiguities.

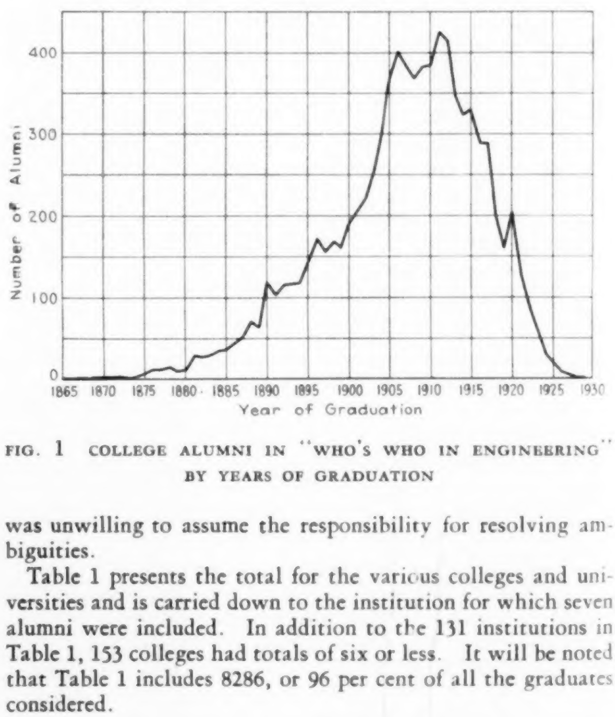


FIG. 1 COLLEGE ALUMNI IN "WHO'S WHO IN ENGINEERING" BY YEARS OF GRADUATION

Table 1 presents the total for the various colleges and universities and is carried down to the institution for which seven alumni were included. In addition to the 131 institutions in Table 1, 153 colleges had totals of six or less. It will be noted that Table 1 includes 8286, or 96 per cent of all the graduates considered.

MORE THAN ONE-THIRD OF THE GRADUATES LISTED ARE ALUMNI OF EIGHT COLLEGES

The concentration in the totals for the leading institutions is rather impressive. Massachusetts Institute of Technology, Cornell, and the University of Michigan contributed 18.65 per cent of the total of 8643 graduates included in this volume of "Who's Who in Engineering," and more than one-third of all the alumni listed were graduated from the first eight colleges.

A study of the contributions of the various types of institutions yields very indeterminate results. For example: of the

[1] President, Rose Polytechnic Institute, Terre Haute, Ind. Mem. A.S.M.E.

TABLE 1 GRADUATES OF 131 COLLEGES AND UNIVERSITIES OF THE UNITED STATES AND CANADA LISTED IN "WHO'S WHO IN ENGINEERING"

No.		Number of graduates	No.		Number of graduates
1.	Massachusetts Institute of Technology	664	65.	Alabama Polytechnic	28
2.	Cornell	562	66.	College of the City of New York	28
3.	Michigan	385	67.	George Washington University	28
4.	Illinois	295	68.	Toronto	28
5.	Columbia	282	69.	Vermont	28
6.	Wisconsin	269	70.	Oklahoma	27
7.	Yale	256	71.	Arkansas	24
8.	Purdue	254	72.	Indiana	24
9.	University of California	207	73.	Virginia	24
10.	Lehigh	201	74.	North Carolina	23
11.	Ohio State University	192	75.	Virginia Military Inst.	23
12.	Harvard	190	76.	Swarthmore	22
13.	University of Pennsylvania	179	77.	Oregon State	20
14.	University of Minnesota	157	78.	Washington State	20
15.	Stanford	145	79.	California Institute of Technology	19
16.	Worcester	145	80.	Colorado State	19
17.	Iowa State	144	81.	Norwich	19
18.	Stevens	122	82.	North Carolina State	18
19.	Rensselaer	120	83.	Queens	17
20.	University of Kansas	119	84.	Tennessee	17
21.	Pennsylvania State	110	85.	Vanderbilt	17
22.	Michigan Mines	96	86.	Cornell College	16
23.	University of Nebraska	93	87.	Washington & Lee	16
24.	U.S. Military Academy	92	88.	Denison	15
25.	Case	85	89.	Mississippi A. & M.	15
26.	Armour	82	90.	North Dakota	15
27.	Colorado Mines	82	91.	Northwestern	15
28.	University of Missouri	82	92.	Rochester	15
29.	University of Washington	82	93.	Valparaiso	15
			94.	Amherst	14
30.	University of Colorado	80	95.	Clarkson	14
31.	Maine	71	96.	Colorado College	14
32.	Rose Polytechnic	71	97.	Bucknell	13
33.	Princeton	68	98.	Nevada	13
34.	Washington (St. Louis)	67	99.	New Hampshire	13
35.	Michigan State	66	100.	South Dakota State	13
36.	Dartmouth	60	101.	Clemson	12
37.	Kansas A. & M.	60	102.	Idaho	12
38.	U. S. Naval Academy	56	103.	Marquette	12
39.	Syracuse	56	104.	Notre Dame	12
40.	Missouri Mines	55	105.	Oklahoma State	12
41.	Brown	48	106.	Rhode Island State	12
42.	University of Kentucky	48	107.	Allegheny	11
43.	University of Iowa	43	108.	University of Georgia	11
44.	Union	43	109.	South Dakota Mines	11
45.	University of Texas	42	110.	Williams	11
46.	Cincinnati	41	111.	Florida	10
47.	Cooper	41	112.	Louisiana	10
48.	Lafayette	40	113.	Arizona	9
49.	Rutgers	40	114.	Colgate	9
50.	Tufts	39	115.	Earlham	9
51.	Brooklyn	38	116.	Highland Park	9
52.	Johns Hopkins University	38	117.	Lewis	9
			118.	Haverford	8
53.	Pittsburgh	37	119.	University of Montana	8
54.	Virginia Polytechnic Institute	37	120.	Oberlin	8
			121.	Trinity	8
55.	New York University	36	122.	University of the South	8
56.	Carnegie	35	123.	Beloit	7
57.	University of Chicago	35	124.	Grinnell	7
58.	McGill	35	125.	Montana Mines	7
59.	Texas A. & M.	34	126.	Montana State	7
60.	Tulane	34	127.	Ohio Wesleyan	7
61.	Georgia Tech	33	128.	Oregon	7
62.	West Virginia	33	129.	Southern California	7
63.	Ohio Northern	31	130.	Tri-State	7
64.	Utah	30	131.	Wyoming	7

first twenty institutions listed, eleven are considered private and nine are state. In this group the state universities have 2022 alumni, while the private institutions have 2866, or 41.3 per cent and 58.7 per cent, respectively. In this same group are included four independent engineering schools and sixteen engineering departments of universities. Of the 8643 alumni listed, 4467 were graduated from private or endowed institutions, 4028 from state universities and colleges, and 148 from the United States Military and Naval Academies.

The comparative success of an institution in training its students might be approximated by calculating the percentage of its living alumni listed in "Who's Who." The author found, however, while collecting similar information for a previous paper,[2] that alumni records are so uncertain and inaccurate that they are too unreliable for fair comparison. For example, it would be almost impossible to get lists of living graduates on the same basis as that on which the distribution of this study has been made. And in the case of the University of Michigan, for instance, alumni of both the college and the engineering school are listed in "Who's Who in Engineering." Obviously, it would not be fair to use either the total number of living graduates of both schools or of the engineering school alone, in calculating a percentage to be compared with a corresponding value for Case or Worcester Polytechnic.

Majority of Engineering Graduates Listed Were in Classes from 1890 to 1920

Again, fluctuations in the size of an institution affect the percentage of its alumni. Most of the engineering graduates in this third edition of "Who's Who" were in the classes from

TABLE 2 DATA ON GRADUATES OF SIXTEEN ENGINEERING EDUCATIONAL INSTITUTIONS OF SIMILAR TYPE

Institution	Founded	Total number of graduates	Graduates in "Who's Who in Engineering" Number	Per cent of total
Michigan School of Mines	1885	1,320	96	7.27
Rose Polytechnic Institute	1874	1,463	71	4.85
Colorado School of Mines	1871	1,722	82	4.76
Worcester Polytechnic Institute	1865	3,098	145	4.68
Massachusetts Institute of Technology	1861	15,804	664	4.2
Stevens Institute of Technology	1870	3,290	122	3.72
Purdue University	1874	7,199 (eng'g)	254	3.53
Armour Institute of Technology	1892	2,646	82	3.09
Case School of Applied Science	1880	3,036	85	2.80
Rensselaer Polytechnic Institute	1824	4,506	120	2.67
California Institute of Technology	..	1,006	19	1.89
Brooklyn Polytechnic Institute	1889	2,400	38	1.58
Virginia Polytechnic Institute	1872	3,003	37	1.23
Georgia School of Technology	1888	3,000	33	1.10

1890 to 1920. An institution which has grown slowly in recent years has a definite advantage in this comparison.

The American Council on Education has recently published a statistical volume on American colleges and universities which includes the total number of degrees conferred by each institution. For institutions of similar type and not much more than sixty years old, ratios based on the total degrees conferred are illuminating. Too much importance must not be attached to the values of Table 2, although as far as they go they are probably as reasonable for comparison as any figures would be.

[2] Interesting in this connection is the article, "Engineers in American Life," an analysis, by L. W. Wallace and J. E. Hannum, of the biographies contained in "Who's Who in America" (1928–1929), published in Mechanical Engineering, December, 1929, p. 899.

The distribution of alumni by years of graduation is given in Fig. 1. The effects of wars and depressions are clearly discernible.

This curve can be considered the normal for the production of graduates who later achieved sufficient success to be included in "Who's Who in Engineering," and for purposes of comparison it has been replotted in the various diagrams of Fig. 2, using groups of five classes and plotting the number in each group as a percentage of the total. When the corresponding diagram for any given institution is compared with the normal for all institutions, a picture of the fluctuations in production for the individual college is secured. When the curve for a college varies greatly from the normal, that institution is not conforming to the general trend. Periods of strength and of weakness are revealed. One must be familiar with the internal history of a college to understand these variations, and the few diagrams presented in Fig. 2 are offered without comment.

If the curve of a college follows the normal very closely, it must indicate a continued level of satisfactory instruction. No institution contributed as many as eight per cent of the total alumni listed, consequently no one institution could have had an important influence on the normal.

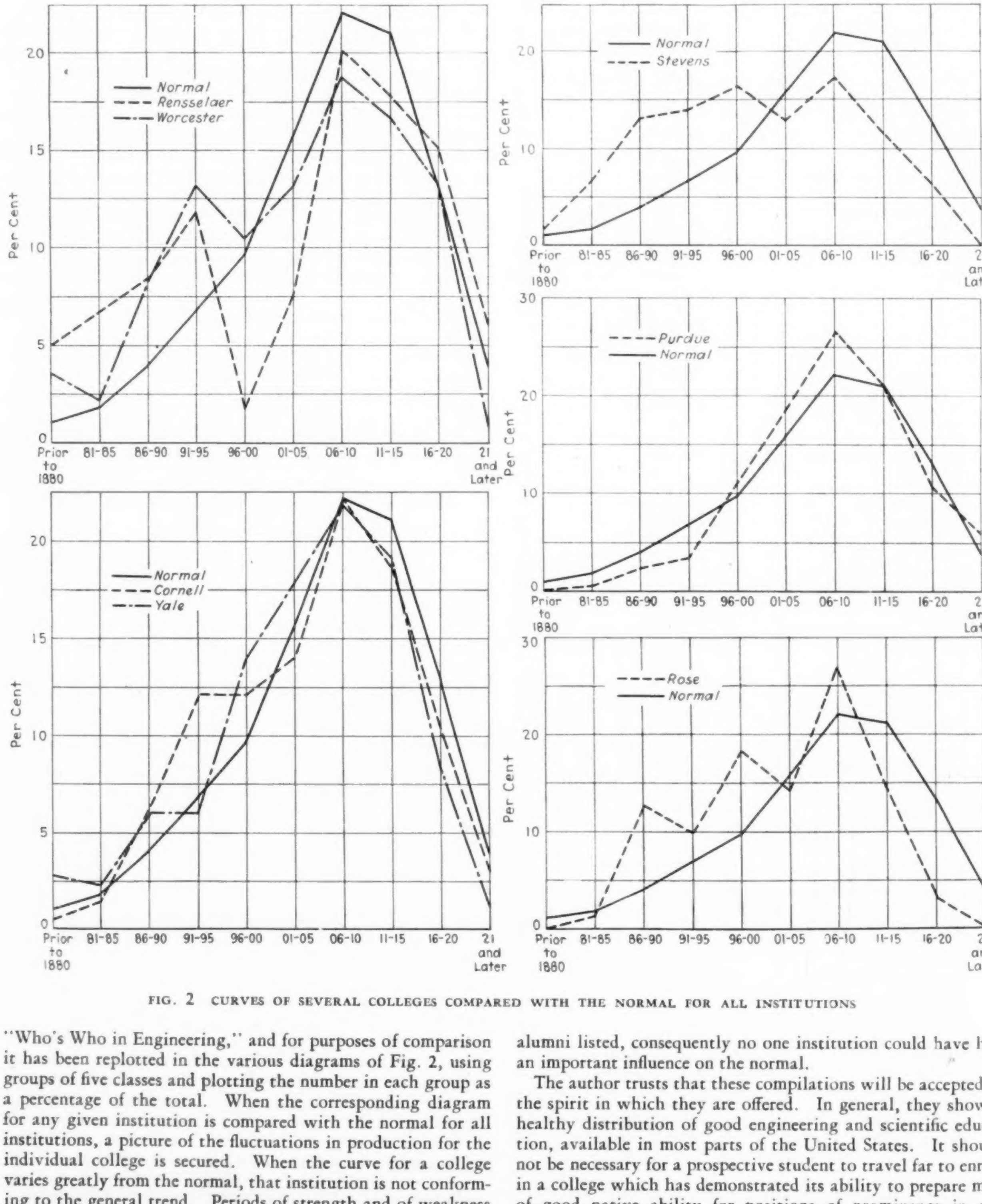


FIG. 2 CURVES OF SEVERAL COLLEGES COMPARED WITH THE NORMAL FOR ALL INSTITUTIONS

The author trusts that these compilations will be accepted in the spirit in which they are offered. In general, they show a healthy distribution of good engineering and scientific education, available in most parts of the United States. It should not be necessary for a prospective student to travel far to enroll in a college which has demonstrated its ability to prepare men of good native ability for positions of prominence in our profession.

The COLD WORKING *of* CANNON

Theory and Practice of Process for Increasing the Elastic Strength of the Metal of Guns and Other Thick-Walled Cylindrical Vessels Subjected to High Internal Pressure

By B. S. MESICK, JR.[1]

IN THIS article the theory and practice of the cold-working process for the manufacture of cannon and thick-walled cylindrical vessels will be discussed briefly, but with sufficient detail, the author hopes, to give a lucid presentation of the problems confronting those engaged in this work. The discussion is divided into two parts, each dealing with a particular phase of the subject-matter. In Part I the theory of the process will be covered, including some fundamentals of cannon design, and making comparisons between the results that can be obtained by the cold-working process and those obtained by other methods of construction. It is believed advantageous to give this matter in a very brief and elementary manner in order to demonstrate the reasons for the adoption of the cold-working method of construction in preference to other methods. In Part II a general description of the apparatus for cold-working cannon and of the process of manufacture is given.

I—THEORY OF THE PROCESS

FUNDAMENTALS OF CANNON DESIGN

Principles of Construction. A cannon is essentially a thermodynamic machine for the conversion of the chemical energy of the powder charge into dynamic energy of translation and rotation of the projectile. It consists simply of a hollow cylinder, made of suitable metal, closed at one end (the breech) and open at the other (the muzzle). It is provided with lands machined on the interior cylindrical surface, whose purpose is to engrave the copper rotating band of the projectile and cause it to rotate the projectile as the latter passes through the bore of the cannon. This rotation is necessary in order to stabilize the flight of the projectile through the air after it leaves the muzzle of the cannon, that is, prevent it from tumbling end over end in flight, which would have disastrous effects on the accuracy of fire.

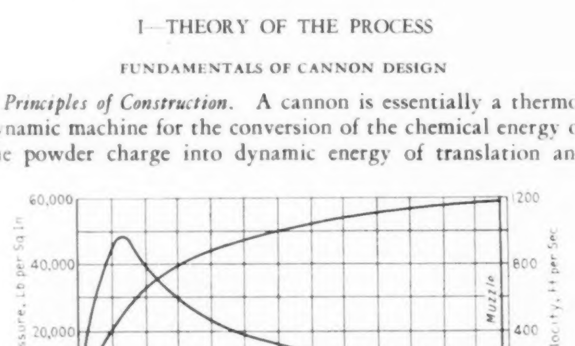


FIG. 1 POWDER-GAS PRESSURE AND VELOCITY OF TRANSLATION OF A PROJECTILE AS FUNCTIONS OF ITS TRAVEL THROUGH THE BORE OF A CANNON

By the methods of interior ballistics, formulas have been developed from which we may obtain the interior pressure of the powder gases acting on the projectile and the velocity of translation of the projectile as functions of the travel of the projectile through the bore of the cannon. These values of pressure and velocity when plotted give curves of the general form shown in Fig. 1. The particular values of pressures and velocities will of course differ for different cannon.

The problem of cannon design and construction therefore resolves itself into that of designing and constructing a hollow cylinder, closed at one end, and of sufficient strength to resist the force of the interior pressure of the powder gases without permanent deformation.

Now when a simple, thick-walled hollow cylinder (i.e., a cylinder with ratio of wall thickness, t, to inside diameter, d_0, greater than 0.03) is subjected to an internal radial pressure, the stresses within the walls of the cylinder are not uniformly (that is, efficiently) distributed. Stresses in three directions, radial, longitudinal, and tangential, are produced by the application of an internal radial pressure. Of these the tangential stresses are the greatest, and are therefore the limiting factors in the elastic strength of cannon. These tangential stresses are tensile stresses which vary from a maximum at the interior of the bore to a minimum at the outside of the cylinder, as shown in Fig. 2. The cylinder reaches its limit of elastic strength when the tangential fiber stress at the interior of the bore is equal to the elastic limit of the metal of which the cylinder is constructed. The maximum internal radial pressure to which the cylinder may be subjected is given by the formula:

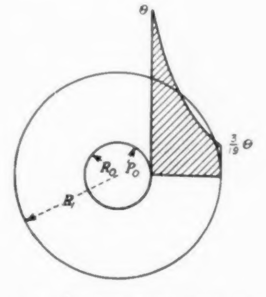


FIG. 2 DISTRIBUTION OF TANGENTIAL STRESS IN SIMPLE CYLINDER HAVING A WALL RATIO OF 3.0 AND SUBJECTED TO AN INTERIOR PRESSURE P_0 SUCH THAT THE METAL AT THE BORE IS STRESSED TO THE ELASTIC LIMIT θ

$$S_t = \frac{{}^2/_3 P_0 R_0^2 - P_1 R_1^2}{R_1^2 - R_2^2} + \frac{{}^4/_3 R_0^2 R_1^2 (P_0 - P_1)}{R_1^2 - R_0^2} \frac{1}{r^2}$$

where S_r = tangential stress at any point whose distance from the axis of the cylinder is r.

$$P_0 = \frac{3}{2} \frac{R_1^2 - R_0^2}{R_0^2 + 2R_1^2} \theta$$

in which P_0 = internal radial pressure, lb per sq in.
R_0 = interior radius of cylinder, in.
R_1 = exterior radius of cylinder, in.
θ = elastic limit of the metal, lb per sq in.

The value of P_0 determined by the above formula is known as the elastic strength of the cylinder.

[1] 1st Lieut., Ordnance Dept., U.S.A., Watertown Arsenal, Watertown, Mass.

An examination of this formula indicated three methods by which the elastic strength of a hollow cylinder may be increased:

a Increasing the value of R_1, that is, making the wall of the cylinder thicker.

b Increasing the value of θ, that is, using a metal of higher elastic limit.

c By appropriate methods of construction so build the cylinder that the interior of the cylinder instead of being under no stress when the internal pressure is zero (cylinder at rest), will be under a compressive stress. The internal pressure will then have to overcome this initial compressive stress before the metal will be stressed in tension. Obviously the elastic strength will be greatest if the metal in the interior fiber is stressed to its elastic limit in compression when at rest. In this case, if it be assumed that the elastic limits in tension and compression are equal, the elastic strength of the cylinder will be doubled.

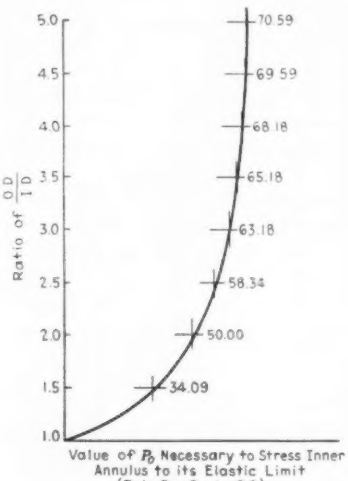


FIG. 3 EFFECT OF INCREASING WALL RATIO ON ELASTIC STRENGTH OF A SIMPLE CYLINDER

$$P = \frac{3}{2}\,\frac{R_1^2 - R_0^2}{R_0^2 + 2R_1^2}\,\theta$$

As the solution of the problem of the designer of a gun or similarly stressed cylinder consists in the judicious application of a combination of these three methods of securing a cylinder that will resist a given internal pressure P_0, taking into consideration the three principles of gun construction that have been mentioned, a brief discussion of these methods of increasing the elastic strength of a hollow cylinder is appropriate.

Effect of Increasing the Wall Ratio. The wall ratio of a hollow cylinder is defined as the ratio of the outside diameter of the cylinder to the inside diameter. In Fig. 3 the values of P_0 in terms of percentages of θ have been plotted for various wall ratios of from 1 to 5. If the curve were extended to infinity, that is, if the wall of the cylinder were considered as infinitely thick, the value of P_0 would be found to be only 0.75 θ. An inspection of Fig. 3 shows that with a wall ratio of 3.0 the interior pressure that may safely be applied to the cylinder is about 63 per cent of the elastic limit of the metal, and that the gain in elastic strength obtained by increasing the wall ratio above 3.0 is very little compared to the increase in weight and cost of the cylinder. It may be stated as a practical rule that a wall ratio of 3.0 should not be exceeded in gun design. The wall ratios actually used by gun designers will usually vary between 1.5 and 2.5, the range 1.5 to 2.0 being used for liners and the ratio 2.0 to 2.5 for tubes. Even with a wall ratio of 3.0 and an internal pressure of 0.63θ, only the metal of the interior of the bore is being used to its full efficiency, that is, being stressed to its elastic limit in tension. The stress decreases rapidly toward the outside, so that at the exterior of the cylinder it is only $^3/_{10}\theta$. (See Fig. 2.)

Higher Elastic Limit in Materials of Construction. Apart from chemical composition, there are two general means of obtaining a higher elastic limit in the metal to be used, namely, (1) heat treatment, and (2) mechanical working, either hot or cold.

Cold working as a means of improving the qualities of the metal is not a new idea, although it has been worked out practically in such a way as to reap a maximum of benefits only within the past few years.

The cold working of metals in general has been discussed in many phases at great length. It is generally agreed that cold working of a metal produces increased hardness, higher elastic limit and tensile strength, and lower ductility, and that the amount of these changes is almost directly proportional to the amount of cold working to which the metal has been subjected. Two methods of cold working steel in gun making are therefore suggested:

1 Construct the gun of a central tube on which are wrapped, under tension, a number of layers of steel wire.

2 Construct the gun of a simple steel tube which has been cold worked radially by a high internal hydraulic pressure. This method is particularly considered here.

In cold working a hollow cylinder, the pressures are applied to the interior or bore of the cylinder, and are of sufficient intensity to permanently deform it, i.e., to increase its diameter and shorten its length. The effect is differential for any right cross-section and is not the same for any two annuli of that right section. This differential straining of the metal is shown in Fig. 2 if we consider the ordinates to represent the deformations produced by cold working by an internal hydraulic pressure P_0, rather than stresses.

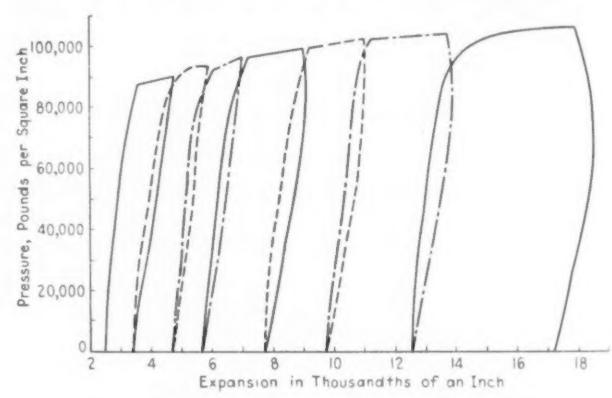


FIG. 4 PRESSURE-EXPANSION DIAGRAM OF CYLINDER

The elastic properties of the cylinder are increased and the ductility reduced, that is, the tensile strength and proportional limit are raised, while the elongation and reduction of area are reduced. There is a progressive increase in proportional limit and tensile strength from the exterior to the interior of the cylinder. This is shown by taking tangential test specimens from a cold-worked cylinder at different radial distances from the center of the bore and subjecting them to the usual physical-laboratory tests.

The increase in elastic strength obtained by cold working a cylinder is a function of the amount of cold working to which the cylinder has been subjected. In cold working a cylinder by internal pressure we expand it, and the measure of expansion (i.e., the amount of cold working) is expressed as the percentage enlargement of the bore, that is, the ratio of the increase in diameter of the bore (after cold working) to the original diameter of the bore (before cold working) expressed as a percentage.

The next question that suggests itself is just how much cold working a cylinder should receive in order to be in the optimum condition of elasticity, ductility, and resistance to shock for

cannon construction. We have seen that though the tensile strength and proportional limit of the metal are increased by cold working, the ductility is decreased, and we have also seen that it is highly desirable to have in cannon and similar metal both a high proportional limit and considerable ductility and resistance to impact or shock.

The *elastic strength* of a hollow cylinder is determined by the maximum pressure in pounds per square inch that can be applied in the bore without stressing the metal at the bore above its proportional limit, that is, without permanently enlarging the diameter of the bore.

In order to determine the effect of cold working, the elastic strength of many experimental cylinders was determined from

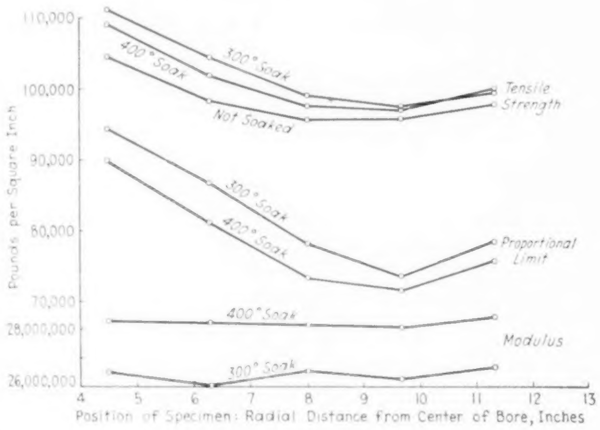


FIG. 5 VARIATION OF TENSILE STRENGTH, PROPORTIONAL LIMIT, AND MODULUS OF ELASTICITY WITH RADIAL DISTANCE FROM CENTER OF BORE

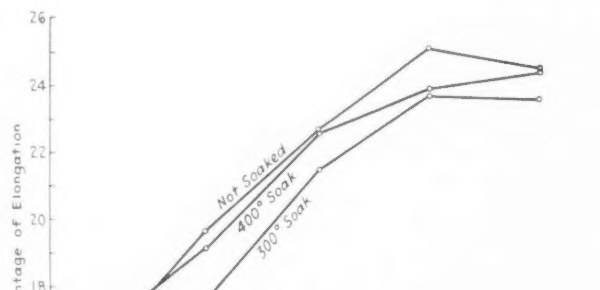


FIG. 6 VARIATION OF PERCENTAGE ELONGATION WITH RADIAL DISTANCE FROM CENTER OF BORE

pressure-expansion diagrams plotted from measurements taken when the cylinders were subjected to an applied internal pressure or load. This was done before and after cold working. It was found that the diagram for a cold-worked cylinder follows one line when loads are increased from zero to the maximum and another line when the loads are released from maximum to zero. The form of such a diagram is a loop as shown in Fig. 4, making it difficult to state accurately the elastic strength of the cylinder. Alternate gradual application and release of pressures below the previously applied pressure reduces the size of this "hysteresis" loop, approaching coincidence on a right line. Similar results may be obtained by giving the cold-worked cylinder a low-temperature anneal at temperatures between 250 C and 400 C. This treatment is commonly referred to as "soaking." Its effect at tempera-

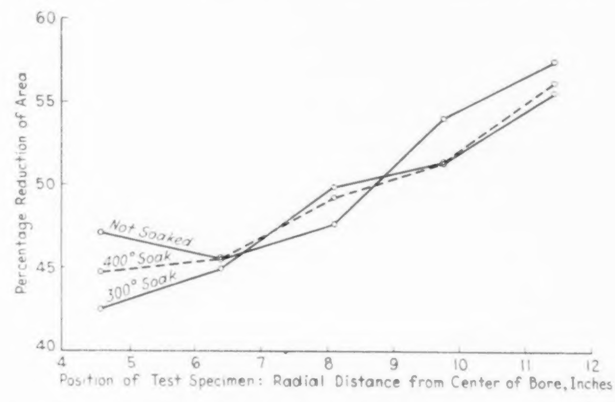


FIG. 7 VARIATION OF PERCENTAGE REDUCTION OF AREA WITH RADIAL DISTANCE FROM CENTER OF BORE

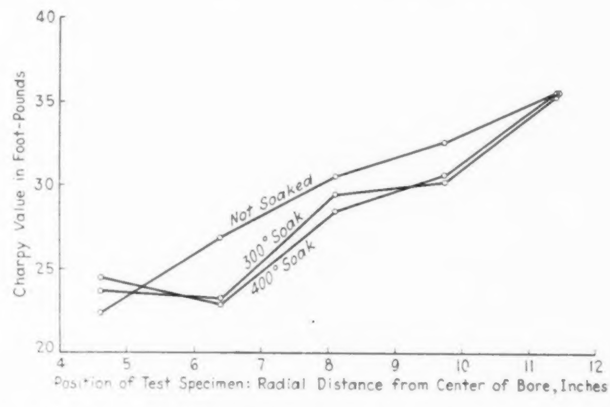


FIG. 8 VARIATION OF CHARPY VALUE WITH RADIAL DISTANCE FROM CENTER OF BORE

tures of 300 C and 400 C is indicated in Figs. 5 to 8. These curves show clearly that soaking at 300 C increases the tensile strength and proportional limit of the metal. Treatment at 300 C gives the most beneficial results for cannon construction. Experiments to determine the effects of soaking at different temperatures brought out the following:

1 Soaking at 121 C or below has negligible effect.

2 Soaking above 200 C removes the hysteresis effect from the stress-strain diagrams.

3 Soaking at 300 C gives an average increase of 15 per cent in the tangential proportional limit of the metal Optimum results.

4 Soaking at 400 C does not appreciably increase the elastic strength of the cylinder, although it does increase the tangential proportional limit of the metal.

5 Soaking at 600 C or above removes all effects of cold working.

As will be shown later, the gain in elastic strength by cold working is greatest for the first 3 per cent of cold working and becomes less and less for each additional 1 per cent that the

cylinder is cold worked. Six per cent enlargement appears to be about the marginal value; that is, if that value is much exceeded there is but little gain in elastic strength, while the ductility of the metal and its resistance to shock are reduced considerably. In one case, however, at Watertown Arsenal, a gun was cold worked to 40 per cent enlargement, and still more than satisfied the ductility and Charpy impact-test requirements. The elastic strength of the gun after cold working and low-temperature anneal can be measured, and if this is done, it will be found that its elastic strength is practically double that of the simple cylinder before cold working. Part of this increase in elastic strength is due to increasing the proportional limit of the metal by cold working. Part of it may be due to initial compression of the metal of the bore due to the process of cold working. How much of the increase in elastic strength should be assigned to initial compression of the bore is partially brought out in the following paragraphs. The remainder is due to increase in proportional limit.

Initial Compression of the Bore. As has been intimated above, cold working produces an initial compression of the bore. Early investigations at Watertown Arsenal showed the existence of initial compression by the taking of strain rings from the cold-worked cylinders. More recent and more accurate investigations have not only shown the existence of initial compression, but have presented a reasonable idea of its magnitude which checks very closely with inferred figures.

In this more recent method, metal is removed by machining from the outer wall of the cylinder being investigated. After cold working the cylinder is very accurately star-gaged, and the diameters of the bore thus obtained are those of a cylinder in stable equilibrium. After a part of the outer wall has been removed, the remaining portion of the wall will seek to adjust itself to the new condition and will seek stable equilibrium. If the outside is in tension and the inside in compression, as each succeeding layer of metal is removed from the outside of the cylinder the stresses holding the inner layers in compression are somewhat relieved and the bore diameters would be expected to enlarge; and that is exactly what happens. The enlargement (change in strain) is proportional to the stress released, so, by carrying the removal of metal from the wall to the maximum, the total strain change and hence a measure of the stress relieved is obtained. Assuming a modulus of elasticity for the metal at the bore of the cylinder, it is possible to compute a reasonable measure of the magnitude of the initial compression produced by cold working the cylinder.

This experimental procedure has been followed with several cold-worked cylinders, some of which have been soaked after cold working. The data obtained from these experiments and others justify the conclusion that cold working produces a compression of the bore in addition to raising the proportional limit of the metal. To quote the results from one experiment: "Cold working a cylinder with a wall ratio of 1.5 about 3 per cent, and soaking at 300 C after cold working, increased the elastic strength of the cylinder 71 per cent over that which it possessed before cold working. Of this increase in strength 31 per cent may be attributed to initial compression of the bore and the remainder, 40 per cent, to increased proportional limit of the metal."

Possible Industrial Uses of Cold Working. Although developed primarily for use in gun manufacture, the cold-working process should have useful applications industrially, especially to cylindrical vessels for containing either liquids or gases at high pressures. One wishing to use the process can safely apply a pressure in the interior that will permanently enlarge the diameter of the bore 6 per cent, then soak at 300 C, and depend upon the cylinder's behaving elastically for any pressure not exceeding that applied to enlarge the bore, provided that the steel before cold working has a Charpy value of not less than 24 ft-lb. If the Charpy value is not less than 32 ft-lb, the bore diameter may be enlarged at least 9 per cent, with proportionate increase in the subsequent safe pressure. The process should be carried out to require the removal of as little metal from the interior walls as possible. If the vessel or cylinder has a relatively thin wall and if a number are to be cold worked, material advantages will result from cold working in a container.

II—APPARATUS AND PROCEDURE EMPLOYED IN COLD WORKING

Cannon may be cold worked by internal hydraulic pressures in two ways:

(*a*) In the open, that is, without any exterior constraints to limit the amount of expansion of the cylinder. As a cannon usually does not have a uniform wall ratio throughout its entire length, but is thicker at the breech end and thinner at the muzzle, the use of this method of cold working involves working different parts of the cannon at different pressures in order to secure a uniform expansion of the bore throughout.

(*b*) In a container. In this method the cannon is placed inside a strong, thick-walled, hollow cylindrical container that limits the expansion of the thinner-walled sections to the desired amount. The use of a container permits the cold working to be accomplished by a single operation, using an internal pressure high enough to cold work the thickest-walled section the desired amount.

The essential apparatus necessary for cold working guns by the container method consists of the following:

1 Suitable means for generating high hydraulic pressures: pump and intensifier.

2 Suitable means for leading the high-pressure water to the interior of the cannon: piping and connectors.

3 Suitable means for controlling the apparatus: valve block.

4 Suitable means for holding the high pressures in the cannon: packings, supported by assembly of end rails, centering pieces, and tie rods.

5 Suitable means for limiting the amount of cold working of the thinner-walled sections of the cannon to the desired percentages: containers.

6 Suitable means for forcing the cannon out of the container after cold working: hydraulic jack in base assembly.

7 Accurate means for measuring the high working pressures: pressure gages.

Practically all of the equipment used in this process must be specially designed for the purpose. The layout of cold-working equipment is shown diagrammatically in Fig. 9, which should be referred to in connection with the description of the various parts of the equipment and the discussion of cold-working procedure.

Any good commercial pressure pump capable of delivering water at the pressures required in the low-pressure part of the apparatus may be used.

The intensifier is very simple in construction and in principle. Low-pressure water is delivered by the pump through the bottom of the intensifier, and acts on the face of the moving piston. The water that fills the interior of the piston is compressed against the ram, the high-pressure water being delivered through a small hole in the ram stem. The capacity of the intensifier is the quantity of high-pressure water it can

deliver to the interior of the work, and is equal to the volume in cubic inches of the space in the interior of the piston below the ram at zero pressure. It is essential that the capacity be at least as great as the volume of the interior space of the work to be filled with high-pressure water when the desired expansion has been obtained. The pipe used must be designed to carry with safety the highest-pressure water expected to be needed. Such pipe of the desired diameter can be obtained commercially for pressures up to 150,000 lb per sq in. The connectors, valve block, and packings must be designed to hold the same maximum pressure. The containers are merely thick hollow cylinders of forged steel, whose interior dimensions correspond to the desired exterior dimensions of the gun or cylinder when expanded for the desired enlargement. The minimum wall ratio of containers should be 4 to 1.

There are several methods of measuring the hydraulic pressures involved in this process, but only one will be described here. A standard commercial pressure gage with a range from 0 to the maximum pressure that can be delivered by the pump is connected to the low-pressure line, and approximate high pressures in the interior of the work may be computed by multiplying the readings of this gage by the intensifier ratio. Accurate determinations of the working pressures are made by means of a sensitive electrical pressure gage, which consists essentially of a coil of manganin wire connected in series on one side of a Wheatstone bridge. The manganin coil is assembled into a housing connected to the high-pressure water line, and is therefore subjected to the same hydraulic pressure as the interior of the work. The principle of the apparatus depends on the fact that the electrical resistance of manganin wire increases directly with the pressure to which it is subjected. The instrument reads pressure directly, as the variable resistance of the Wheatstone bridge is calibrated and graduated in pounds per square inch of pressure instead of electrical units of resistance.

The general procedure involved in this process is probably obvious to the reader, and the details must be adjusted to the particular problem of the user of the process. The forging to be cold worked is received from the machine shop machined to the dimensions prescribed on the drawing of the gun "preparatory for cold working." The first step in cold working is to measure carefully all important dimensions of the forging and check them with those shown on the drawing. This step is essential, as a slight variation in diameter or in length of a taper will seriously affect the results obtained from the cold working. The outside of the forging is then covered with a heavy coating of cup grease, lifted at one end, and lowered into the container. Filler pieces of steel and wood are inserted in the bore. These are used merely to fill up space in the bore which would otherwise have to be filled with water. The upper piece is made of wood in order to facilitate the adjustment of the filler as to length. The remaining space in the bore of the forging is then filled with water, which is poured in by hand, and the remainder of the apparatus assembled as shown in Fig. 9.

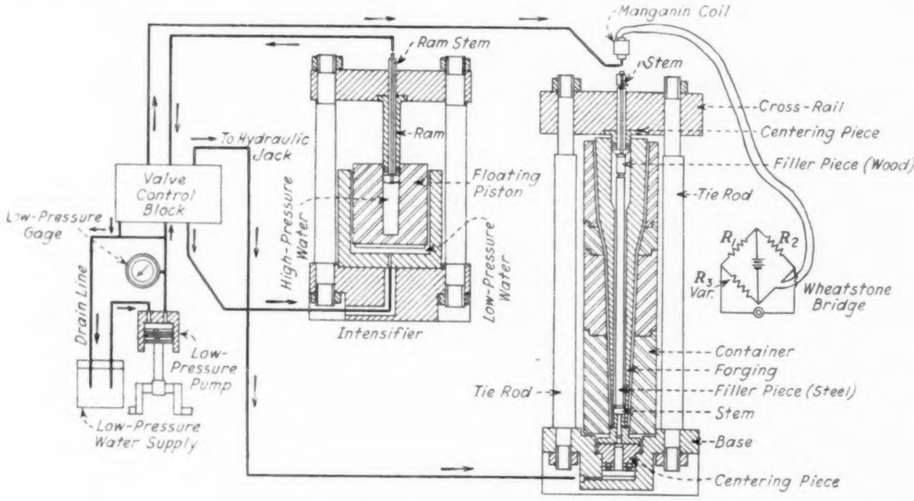


FIG. 9 LAYOUT OF COLD-WORKING EQUIPMENT

The pump is then started, the high pressure turned on, and the cold working begins. The application of pressure in the bore of the hollow cylinder expands all diameters of the cylinder. Upon release of the pressure to zero all diameters will decrease, and the amount of reduction is called "elastic recovery." If sufficient pressure is applied all diameters will have been enlarged, the amount of enlargement of each being equal to the expansion while the pressure was acting minus the elastic recovery. The ratio of the enlargement of the exterior diameter to that of the interior diameter is principally a function of the amount of enlargement of the interior diameter and of the ratio of the original exterior diameter to original interior diameter of the cylinder. To produce a specified enlargement of the bore of a given cylinder, sufficient pressure must be applied therein to expand the exterior diameter a certain amount while the pressure is acting. The diameter of the hole in the container, at each right section, must be made equal to the exterior diameter of the cannon at the same cross-section when expanded by the pressure applied in its bore to enlarge the latter by the desired amount. If a cannon is inserted in a properly made container, it is obvious that the pressure can be increased to that required for the thickest wall section of the cannon as rapidly as the pressure-generating equipment will permit. When the applied pressure increases to that required to expand the bore in the thinnest wall section by the required amount, the exterior surface of the cannon at that section will be in contact with the interior surface of the container and cannot be further appreciably enlarged as the pressure is increased to that required for the thickest wall section. As the pressure is increased, the bore of the container

(*Continued on page 710*)

STANDARD TESTS *for* METAL-CUTTING TOOLS

Urging the Standardization of Conditions and Procedure for Comparative Shop Tests of Turning Tools and Tool Materials

By ROBERT C. DEALE[1]

While there has been much discussion of the comparative value of the materials of which metal-cutting tools are made, little has been done to determine the relationships of cutting speed, tool life, feed, and depth of cut in various metals with different tools since the classical experiments reported by Frederick W. Taylor twenty-five years ago. Many data have been published, but when it is desired to compare two or more sets of results, it is usually found that they are not at all comparable. Tool life is seldom given, while the description of the tool form, the specifications of the metal cut, and the material of which the tool is made are frequently incomplete. Information is often given as to the number of pieces that have been made with a single grinding of the tool, but this is seldom of value in comparing the tool in question with one used on an entirely different part or in setting up feeds and speeds for use on another piece.

The data supplied by the manufacturers of tool steel, stellite, and cemented tungsten carbide are generally so vague that users of these materials cannot take full advantage of the properties possessed by the tool. A shop that wishes to push tool performance to its economic limit must run its own tests and secure its own data. Few shops are willing to do this, and few have the necessary knowledge to run such tests on laboratory basis, even though it is possible to do the work in the regular machine shop. As a consequence, few other than the large production shops have any real data on the properties of cutting-tool materials and their true comparative values.

While extravagant claims are made for some of these materials as compared with others, it is practically impossible for the production manager of a shop to take the published data on the subject and figure whether it will pay him to change from one type of tool to another. In most shops the mechanic is given a tool and is allowed to work out his own feeds and speeds by trial and error. The author has found that mechanics, unless given assistance as to the correct feeds and speeds to be used, will invariably fail to find the most desirable combination for use on a given cut. Charts giving standard speeds and feeds should be made up and posted at each machine for reference as necessary, or instruction cards, specifying the feed and speed for each cut, should be furnished.

To make full use of any charts or data, they should be presented so that they may be used directly in setting feeds and speeds for any part in any shop where the power of the lathe and the size and type of the tool are substantially the same as those in the test in question. In addition, the results should be directly comparable with those secured on any equivalent test.

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TOOL LIFE

To insure uniformity of results, so as to allow direct comparison, and facilitate shop use, cutting speeds should be given on the basis of some standard tool life, preferably a time that will correspond with an economical tool life in shop use.

Taylor did a major part of his work on the basis of a twenty-minute tool life, running most of his tests the full time. However, he found in the course of his work that with a given high-speed-steel tool, making a specific cut in a given quality of metal, the life of the tool in terms of cutting speed could be represented approximately by the empirical equation:

$$VT^n = c$$

in which V = the cutting speed in feet per minute

T = the tool life in minutes

c = a constant, depending for its numerical value upon the exact cutting conditions

n = a constant, which appears to depend largely on the material of which the tool is made, although the form of the tool as well as the general testing conditions may also affect it. H. J. French and T. G. Digges[2] concluded that the exponent $^1/_7$ fitted the results of all published experiments quite closely in the case of high-speed tools used for roughing cuts in steel. In another paper[3] the same two authors conclude that this exponent should be $^1/_{10}$ for finishing cuts in steel with high-speed-steel tools. Mr. Digges[4] has also shown that the experimental results with cemented-tungsten-carbide tools were closely represented by this equation with $n = {}^1/_5$. No data are available for stellite. While no exact information on the relation between cutting speed and tool life has been published, Taylor reports[5] that when cutting cast iron the tool life is somewhat greater than would be given by the steel formula.

DATA NECESSARY IN METAL-CUTTING TEST

To be complete, the results of any metal-cutting test should include the following data:

1 Cutting speed
2 Feed

[2] See "Rough Turning With Particular Reference to the Steel Cut," Trans. A.S.M.E., vol. 48, 1926, p. 533.

[3] "Turning With Shallow Cuts at High Speeds," Trans. A.S.M.E., 1930, paper MSP-52-6.

[4] "Cutting Tests With Cemented-Tungsten-Carbide Lathe Tools," Trans. A.S.M.E., 1930, paper MSP-52-13.

[5] "On the Art of Cutting Metals," p. 161, par. 709.

3 Depth of cut
4 Tool life (with a notation as to the method of determining tool life)
5 Horsepower required (not absolutely necessary, but desirable)
6 Type of metal cut, giving complete identification, so that the test might be repeated if desirable. Steel may be designated by the S.A.E. number or by analysis. A hardness test, such as Brinell or Rockwell, is desirable, particularly if the steel is heat-treated before the test. Tests on cast iron should report the presence of any important alloying elements, such as nickel, while the Brinell number should be given as the best available indication of the hardness of the metal.
7 Material of tool. The heat treatment of high-speed-steel tools should be in general accordance with the recommended practice for heat treatment of the American Society for Steel Treating.
8 Dimensions of the tool
9 Shape of the tool
10 Rake and clearance angles of the tool
11 Description of machine on which the test was made. (As this is largely in order to indicate the possible influence of the machine in causing tool breakdown, any abnormal looseness in the machine should be reported, because of its great effect on the results.)
12 Definition of tool condition at the end of the test and method of determining the endpoint
13 The coolant used, if any, and the approximate quantity used per minute.

STANDARDIZATION OF TEST PROCEDURE

Of the above, particularly in those tests designed to measure the relative value of various tool materials, there are a number of points that might well be standardized, in order to facilitate the comparison of results and make comparisons more reliable.

The author believes that the tool life should be standardized at a period which would represent average shop use between grindings, and that sixty minutes meets the requirements of the ordinary machine shop better than any other period. To secure economy of time and materials, tests should be made at a speed which will give a much shorter life, preferably five to fifteen minutes, and the results reduced to a sixty-minute basis by the use of Taylor's equation, which, for this purpose, may be reduced to:

$$\frac{V}{V'} = \left(\frac{T'}{T}\right)^n \quad \text{or} \quad V' = \frac{V}{(T'/T)^n}$$

where V = the speed during the test
V' = the speed at the desired standard tool life (suggested as 60 min)
T = the tool life on test in minutes
T' = the standard tool life in minutes (preferably 60 min)
n = $^1/_7$ for roughing cuts with high-speed-steel tools
= $^1/_{10}$ for finishing cuts with high-speed-steel tools
= $^1/_5$ for roughing cuts with cemented-tungsten-carbide tools

Before the first test cut is taken from a piece of stock, a light truing cut should be taken over it to make sure that the test cut will be of constant depth. Similarly a truing cut should be taken where a previous cut has been made with very heavy feed, or where the test piece is tapered. Any glazing of the surface caused by failure of the tool should be removed before commencing a test cut.

To insure a constant test speed, the work piece should preferably be long enough to cause failure of the tool in making a single cut over it. Few machines have a speed control accurate enough to make it certain that a second cut will be made at exactly the same surface speed as a previous one, and consequently an error will be introduced if two or more cuts should be taken in a single life test. Results of greater accuracy will be secured if several tests for every combination of feed and speed are averaged.

If a series of feed and speed combinations is tried, and if the results after they have been reduced to a standard life basis are plotted, a curve such as those shown in Fig. 1 will result.

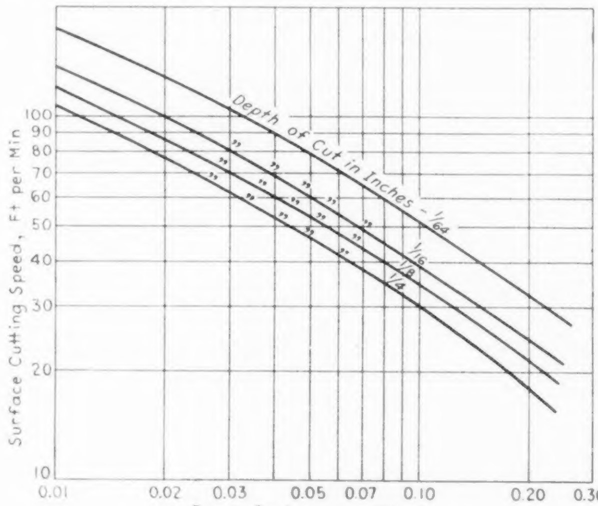

FIG. 1 CUTTING SPEEDS AND FEEDS FOR VARIOUS DEPTHS OF CUT
($^1/_2$-in. high-speed-steel turning tool cutting cast iron of 170 Brinell hardness.)

These curves have been replotted from Taylor's "On the Art of Cutting Metals," and are based on a tool life of thirty minutes. Test inaccuracies are very quickly revealed by such curves, making it possible to check results that are at variance with the bulk of the readings.

For tests designed to compare the quality of one cutting tool with another, the metal cut might well be standardized. Because of the fact that it is used in every shop, it is recommended that S.A.E. 1020 steel be used for all tests of this sort, except those on which it is desired to show the value of the tool for cutting cast materials, when an unalloyed gray cast iron having a Brinell hardness of 150 to 180 may be used as a basis.

To test the material of the tool only, a standard roughing tool might well be used. As the size of the tool affects the result, this also should be standardized. The author believes that a relatively small tool, in addition to being economical, represents the largest number of tools in use. A forged tool, $^5/_8$ by $1^1/_4$ inches, should give results in line with those that would be obtained in a majority of shops. While a round-nose tool is generally used for roughing, the author prefers a tool of the type shown in Fig. 2, with rake and clearance angles suitable for the material being cut. For S.A.E. 1020 steel, angles approximately as follows have been used:

A = top rake, 4 to 6 deg
B = side rake, 8 to 12 deg
C = side clearance, 6 to 12 deg
D = front clearance, 10 to 15 deg

The author believes that more consistent results can be obtained by dry cutting than by cutting with a coolant, as many lathes have no provision for the use of coolants and because even when such provision is made the quantity of coolant varies very greatly. The results secured without coolant are more readily duplicated; consequently it is recommended that all data except those designed to show the effect of the use of coolant be on the basis of dry cutting.

A SUMMARY OF THE ELEMENTS TO BE STANDARDIZED

The standardization of the following elements in testing metal-turning tools will be of great advantage in permitting direct comparisons of different sets of tests:

1 *Form.* All data shall be presented by means of curves showing the variation of cutting speed for each depth of cut and for each given size and form of tool.

2 *Tool Life.* The cutting speed shall be computed from the average tool life by means of the equation $VT^n = c$, in terms of a 60-min tool life. If possible, six to eight tests shall be made for each condition investigated and the cutting speed computed from an average of these results. No cut of less than five minutes shall be used in developing standard data.

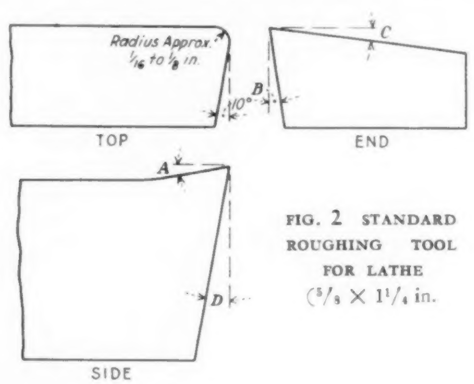

FIG. 2 STANDARD ROUGHING TOOL FOR LATHE ($^5/_8 \times 1^1/_4$ in.

3 *Metal Cut.* All data made up for the purpose of comparing tool material and form shall be based on the cutting of S.A.E. 1020 steel, or of gray unalloyed cast iron having a Brinell hardness of 150 to 180.

4 *Tool.* All data made up for the purpose of comparing tool material and form shall be based on the use of a standard $^5/_8$-inch by $1^1/_4$-inch forged roughing tool, ground as shown in Fig. 2.

5 *Preparation of the Work Piece.* Before any test cut is taken the test piece shall be inspected, and if it is found to be eccentric, tapered, rough from a preceding cut taken with an unusually wide feed, or glazed from a tool failure, a light truing cut shall be taken to make sure that the test cut is uniform throughout.

6 *Test Cuts.* When tests are being made on standard machine tools, in which the speed steps are relatively coarse, it is recommended that the piece to be cut be long enough to insure the destruction of the cutting edge of the tool in a single pass over it.

7 *Coolant.* All standard results shall be based on dry cutting, although additional work showing the effect of coolant is highly desirable.

MANUFACTURERS URGED TO PROVIDE STANDARDIZED DATA

There are relatively few published data covering the feeds and speeds which may be used with modern cutting tools. The Bureau of Standards has done valuable work on high-speed-steel tools, cutting machinery, and nickel steel, and has also done some work with cemented tungsten carbide. A great opportunity exists for the collection of data on the cutting of all the usual materials of machine construction, particularly cast iron, brass, bronze, aluminum, chrome-nickel steel, and cast steel. The author believes that it is the responsibility of the manufacturers of cutting tools to furnish a series of curves showing the performance of their tools, with the various metals commonly cut. At present the sale of tools is based on general performance that cannot be checked by the purchaser. Should data on a known basis be put in the hands of the shop executive, enabling him to set accurate feeds and speeds for various jobs and allowing him to check results from time to time, this important part of the work of the shop would be put on a much more satisfactory basis. Such data could be made up along the lines outlined in this article. Tools believed to be defective could be checked against a known standard. Companies having a superior product would be in a position to prove it. Production from existing equipment could be appreciably increased. Finally, a great step would be made toward the putting of the cutting of metals on the scientific basis which Frederick W. Taylor visualized.

The Cold Working of Cannon

(*Continued from page 707*)

will expand elastically only, if properly designed; this elastic expansion is relatively small in amount and can be allowed for in fixing the diameter of the container. Containers should so be designed and made that the elastic expansion produced by the maximum pressure to be used in the cannon will be a minimum. The length of a cannon decreases appreciably during cold working. Allowance for this shortening must be made in the lengths of the tapered sections of the hole in the container. The design requirements of some types of gun carriages require cylindrical sections on the exterior surface of the cannon, which results in a large reduction in the exterior diameter within a short length and the formation of a shoulder. Similar allowance for longitudinal shortening of the cannon must be made in locating the corresponding shoulder in the container. The relative locations of the bottom surface of the container and of the muzzle end of the gun, which rests on the bottom centering piece, are fixed by the bottom rail. All lengths to junctions of tapered surfaces and to shoulders should be measured from the muzzle end of both the cannon and container. Contact of the muzzle face of a correctly machined cannon on the bottom centering piece, when the cannon is inserted in the container, insures correct relative location of junctions of tapered surfaces and of shoulders. The container enables the desired enlargement of the bore of the cannon to be obtained with surprising uniformity. It materially reduces the length of time required to cold work each cannon. The making of the exterior surface of the cannon and the hole in the container in conical lengths, or of several tapered sections, assists in the removal of the cannon from the container after cold working. A hydraulic jack in the bottom rail, by which pressure can be applied to the muzzle end of the cannon, through the centering piece, will prove necessary in some cases to start the cannon out of the container when it refuses to move easily, principally because of bending of the forging during the process.

Control of

OPERATING EXPENSES

An Application of Statistical Methods

By ROBERT TEVIOT LIVINGSTON[1]

IN THIS modern industrialized period the governing feature of most of the phases of our lives is the economic one. Scientific achievement is definitely limited by commercial application, and commercial application is in turn limited by economic considerations. Engineering economic analysis in the past has been mainly theoretical, concerned with the propriety of installing a piece of apparatus and the consequent theoretical saving which would be obtained thereby. The apparatus installed, the theoretical saving usually has not been checked to discover if the expectations have been realized.

Theoretically, all engineering enterprises are engaged in primarily to supply an economic need and, secondarily in theory, to produce a profit. The only source of return to the owners is from the revenue, and it is desirable to spend as little of this revenue as possible. Therefore it is important to be able to analyze expenses so that the possibilities of reductions may be determined. Fundamentally, the purpose of any operation is to turn out the desired product as cheaply as possible, and hence the final answer to almost all questions concerned with electric steam power plants, for example, will be found in an analysis of the costs. Equipment may be purchased and installed which is supposed to increase the efficiency or decrease the heat units per unit of output, but unless there is shown a decrease in the total cost of operation, such equipment has failed of its purpose. Low heat rates and high efficiencies of boilers, turbines, and condensers are very interesting technological achievements; but unless the results of such highly efficient equipment are shown in lower costs they are expensive playthings. All engineering designs are based on assumptions of physical characteristics or competitive possibilities. Unless these assumptions are well chosen, the resulting design may be economically unsound although technically excellent.

The correct method of studying the efficiency of operation is to analyze the costs as well as the physical factors conditioning these costs. The two are not independent but are mutually interdependent and a complete analysis will consider both, giving due weight to the physical factors when inspecting the latter. In many cases, however, it becomes necessary to check and analyze operations from the cost figures alone when complete data are not available for thorough study and when the plant under consideration is so far away that personal inspection is practically impossible. In cases such as these a mathematical analysis is the only approach, and it will yield results which will at least be useful.

This paper presents a procedure by means of which costs may be mathematically analyzed and demonstrates when a variation in cost has significance. The procedure consists of the application of statistical methods to an engineering problem.

Reduced to its simplest terms, procedure in the analysis of cost relationships may be said to consist of four parts:

(1) Determination of the "best" relationship between operating cost and output by the method of least squares

(2) Calculation of the significance of the equation thus determined by statistical methods

(3) Calculation of limits of variation which are not significant and the consequent establishment of a "control band"

(4) Alteration of form of equation to the familiar unit-cost type.

THE COSTS TO BE ANALYZED

There are three possible fields in which cost analysis may be made: recorded costs, unit costs, and marginal costs. The fundamental data in any case are those prepared by the accounting department from the ledgers and are the recorded costs—month by month. Very little can be gained from a consideration of the recorded costs alone without taking account of the factors which govern and produce their variation. This is done by considering the unit or the marginal costs which are derived from the fundamental accounting data.

A marginal—or differential or increment—cost is that small added cost at which it may be considered that a small addition of output is and can be produced. Or if:

$$\text{Expense for } A \text{ number of units of output} = B \text{ dollars}$$

then

$$\text{Expense for } A + \Delta A \text{ units} = B + (M \times \Delta A)$$

where M is the marginal cost. This assumes that at any given point the curve of total expense vs. output is a straight line, and if M is a constant throughout the range under consideration then the marginal-cost equation is also a straight line. For the purposes of this paper this special condition is considered to exist. Fig. 1 shows a typical marginal-cost curve whose equation is

$$y = 3 + x \qquad [1]$$

where y is the actual cost and x is the output. The value of A is seen to be 3 and of M to be 1.

A unit cost is the average cost at which each unit of output is considered to have been produced in order to obtain the cost which was actually incurred. Or, as it may be written:

$$\text{Expense for } A \text{ units of output} = y' \times A$$

In a similar manner:

$$\text{Expense for } B \text{ units of output} = y'' \times B$$

and

$$\text{Expense for } N \text{ units of output} = U_n \times N$$

Fig. 2 shows a typical unit-cost curve whose equation is

$$y' = 3/x + 1 \qquad [2]$$

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It may be seen that Equations [1] and [2] are related by the fact that by definition

$$y' = y/x \quad \ldots\ldots [3]$$

By substitution in Equation [2]

$$y/x = 3/x + 1$$

and multiplying through by x the original Equation [1]

$$y = 3 + x$$

is obtained.

The unit-cost curve may be seen to be of the hyperbolic form, a general equation of which is

$$(x - a)(y' - b) = C \quad \ldots\ldots [4]$$

But when a, the constant on the x-axis, is omitted on the assumption that when the output is zero some cost remains (see

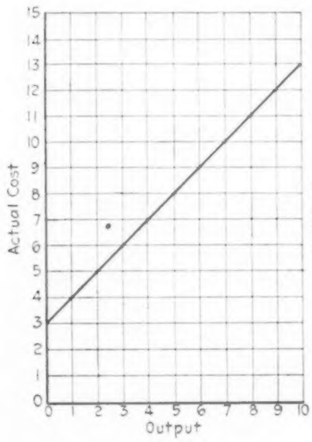


FIG. 1

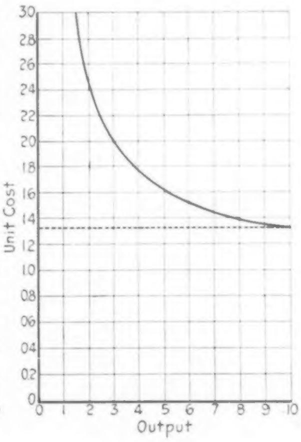


FIG. 2

the marginal-cost curve) and the unit cost is infinity, the equation becomes

$$y' = c/x + b \quad \ldots\ldots [5]$$

which is the identical form of Equation [2]. It may therefore be said that the marginal- and the unit-cost curves are merely transpositions and only one need be considered.

In order to determine these equations either one may be set up and by substitution of the given data the coefficients may be determined. The other equation may then be determined by transposition. The marginal-cost equation is the simplest to obtain as it is assumed to be a straight line and it yields to the standard statistical tests of significance, while to solve for the hyperbola of unit cost requires quite involved calculations possessing great possibilities of error.

FITTING THE CURVE TO THE DATA

Given the operating results of any plant over a period of time, the first step is to fit the proper curve to the data. The problem of fitting a curve to any array of data is one that admits of much discussion and there is no necessarily correct and unique method. The problem consists of the two parts which are quite distinct and separate. They are:

(a) The choice of the functional form
(b) The fitting of the function to the data.

The choice of the functional form is based on the theory of variation of the dependent variables. General laws cannot be laid down which will fit every case. It is in this first part where the majority of trouble occurs. It is obvious that unless the proper or nearly proper functional form is chosen, peculiar or even ridiculous results may occur. Unless the data cover a sufficiently broad space of variation of both factors to definitely prove otherwise,[2] the straight-line marginal-cost equation should be used. It has the enormous advantage of being simple to determine and use, and furthermore it is as accurate as the basic data warrant. This is particularly true in view of the fact that the straight line itself is not to be used but rather a band spaced about the straight line at such a distance that a definitely predetermined proportion of the data will fall within this band. Particularly in the analysis of cost data any theoretical variations from the linear relationship will be of such a minor nature that even the theoretically correct curve will fall within this band. Therefore it may be said that except in an unusual or special case the use of a second-degree, a discontinuous, or a broken curve is seldom warranted.

Having chosen the functional relationship it then remains to fit this function to the data. There are a large number of possible methods of fitting, which may be grouped under the following heads:

(a) Selected points
(b) Grouping[3]
(c) Moments[4]
(d) Least squares[5]
(e) Other miscellaneous methods.[6]

Of these various methods the solution by least squares is probably the most valuable. The first two methods will yield variously different results depending, in the first case, upon the judgment of the person fitting the curve, and in the second, on the method of grouping used, while with least squares but one unique solution is obtained. Besides this one advantage, it gives the minimum standard error,[7] and therefore the closest generalization about the line. Its chief disadvantages are that the calculation is laborious, though not at all difficult, that it gives undue weight to extreme variation (because the square is introduced), and mainly because it is misunderstood.

The least-squares solution minimizes the standard deviation, or as it may be stated, the square root of the sum of the squares of the differences between the actual value of y and the value given by the equation is a minimum. The method of procedure is familiar to most engineers. Two normal equations are obtained (when two variables are used) by successively multiplying each of the original observation equations by the coefficients of the two unknowns and summing the equations thus formed from the original observational equations, i.e.,

$$\Sigma y = nA + B\,\Sigma x$$

$$\Sigma xy = \Sigma xA + B\,\Sigma x^2$$

These two equations are then solved simultaneously.

DETERMINATION OF THE SIGNIFICANCE OF THE EQUATION DERIVED

The fact that an equation obtained by the method of least squares has the form

$$y = A + Bx$$

[2] J. Blakeman, "On Tests of Linearity of Regression." *Biometrica*, vol. 4 (1906), pp. 332–350.

[3] *Philosophical Magazine*, 6th Series, February, 1920, p. 177; May, 1924, p. 816.

[4] "Handbook of Mathematical Statistics," Houghton Mifflin Co., p. 68.

[5] Whittaker and Robinson, "The Calculus of Observations," 2d Ed. Blackie and Son, p. 209.

[6] "F. Y. Edgeworth's Contribution to Mathematical Statistics." The Royal Statistical Society, p. 103, "The Method of Situation."

[7] See explanation of statistical terms given later.

does not mean that this equation is the correct equation or that it has any real significance. The shape of the curve may be incorrect or there may be other causal factors beside the variation with x. In all observational data, be it costs or physical variation in experimental work, there are certain variations which are due to chance, and before any equation may be said to be significant it must be known what the probability is of obtaining such a variation by chance alone.

Before it is possible to test the significance of any equation, certain terms common in statistical practice must be introduced, defined, and explained; i.e., the standard deviation, the standard error of estimate, and the correlation coefficient. It must first be appreciated that any equation such as

$$y = A + Bx$$

is primarily useful in estimating values of y in terms of variation in x, or, as it may be said, that the variation in y is accounted for by variations in x. The test of whether there is any variation of y with x is whether a value of y given by such an equation more nearly approximates the true value than an arithmetical average would.

The *standard deviation*, the symbol for which is the Greek letter σ (sigma), is the square root of the mean of the squares of the differences between the actual values of y and the average of the y's. This is also often called the "root-mean-square deviation."

The *standard error of estimate* is also a "root-mean-square deviation," but it is taken from the assumed functional relationship. In other words, the deviations or differences are all measured from the curve (or line). The standard error of estimate gives a measure of whether a reasonably good functional relationship has been assumed. If the standard error is not considerably different from the standard deviation, it is indicative that the accuracy of estimate has not been greatly improved by the introduction of the variable. The standard error of estimate is generally represented by the symbol S.

These two values in themselves mean very little, but they have been combined to form the single term called the *correlation coefficient*, the letter r being used for this term. It was derived by Karl Pearson[8] and its value is given by

$$r^2 = 1 - S^2/\sigma^2 \qquad [6]$$

It may be seen that where S approaches σ, the value of r will decrease, reaching zero when they are equal. This would indicate that there is no relationship between the two assumed variables. On the other hand, as S becomes smaller and smaller in relation to σ, the value of r becomes larger and more nearly approaches 1.00, at which value a perfect correlation would be indicated. It is therefore seen that in general, large values of r indicate that the functional relationship expressed is good, while small values indicate it is poor. However, that is all that can be said. The correlation coefficient in itself has no physical significance and a value of r of (say) 0.800 cannot definitely be stated as showing that the relationship expressed is good, bad, or indifferent. The real significance of this can only be told when it is known what is the probability of getting such a coefficient by chance, and in order to know this the number of cases under consideration must be known. This may be determined by the use of the curve (Fig. 3) adapted from R. A. Fisher's Table V.A.[9] On this chart four zones are shown, varying from the class where the relationship definitely is not significant to where it has a high probability of significance. The name of the zone on the chart and the probability of getting such a correlation coefficient by chance are:

Range of	Letter	Probability by chance
Lack of significance	D	more than 1 in 10
Doubtful significance	C	from 1 in 10 to 1 in 20
Partial significance	B	from 1 in 20 to 1 in 100
Definite significance	A	less than 1 in 100

From this chart it may be seen, for example, that a value of r, the correlation coefficient, equal to 0.5 has little significance if there are only ten cases under consideration but is highly significant if there are fifty. Values of r in the areas below B indicate that it is definitely unsafe to generalize from the assumed relationship.

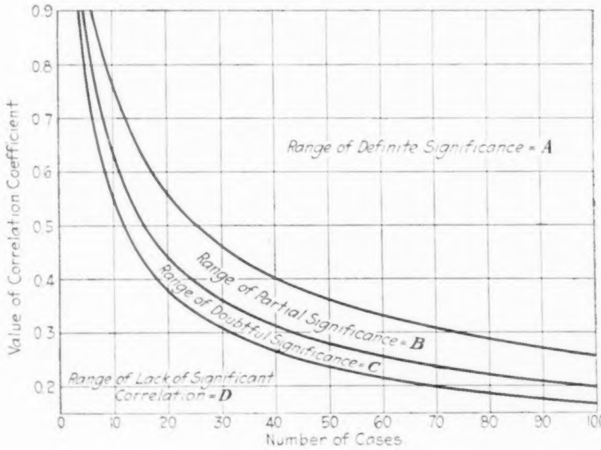


FIG. 3 STANDARD TESTS FOR THE SIGNIFICANCE OF THE CORRELATION COEFFICIENT

(Adapted from R. A. Fisher's Table V.A.)

DETERMINATION OF THE LIMITS OF VARIATION

Having obtained curves and tested their significance, the next step is to set up the limits of chance variation so that the bands may be computed either to determine the significance of any variation or for use as managerial guides. The band is determined by plotting above and below the equation of the curve other curves at a distance equal to a preassigned chance variation.

In an array of data which form a "normal" distribution of residuals it is known that 50 per cent of the cases will fall within a band on either side of the equation equal in width to 0.6745 times the standard error. This distance is known as the probable error. But this presupposes a normal distribution, and this has not been proved to exist for cost data. It is much more general, and in this case more reasonable, to use the Tchebycheff inequality[10] and arbitrarily set up a band of chance probability. By this criterion it may be said that

$$P(\lambda\sigma) \geqq 1 - \frac{1}{\lambda^2} \qquad [7]$$

where P is the probability and λ is a multiple of the standard deviation. In other words, no matter what the distribution is,

[8] The development of this function may be found in any good text on statistical theory; see, for example, Rietz, "Mathematical Statistics," Open Court, p. 77.

[9] R. A. Fisher, "Statistical Methods for Research Workers," 2d Ed. Oliver and Boyd, p. 176.

[10] Tchebycheff, "Des Valeurs Moyennes." *Journal de Mathematique*, (2), vol. 12 (1867), pp. 177–84. An excellent translation may be found in Smith, "Source Book of Mathematics," McGraw-Hill, and an admirable summary in Rietz, *loc. cit.*, p. 28.

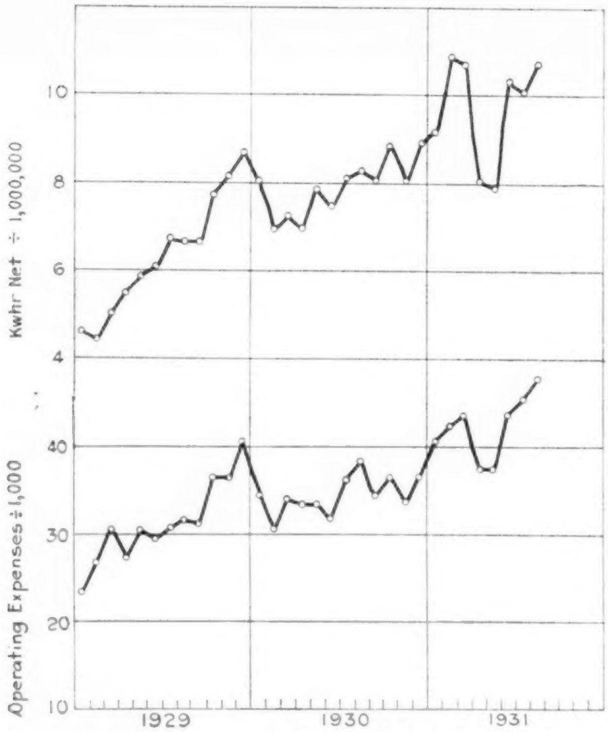


FIG. 4 NET GENERATION AND OPERATING EXPENSES VS. TIME

TABLE 1 STATION OPERATING EXPENSES AND OUTPUT

	Expenses, dollars	Output, kwhr	Unit cost, cents per kwhr
1929			
Jan.	23,649.08	4,638,876	0.5098
Feb.	26,860.48	4,400,000	0.6105
Mar.	30,429.69	5,080,000	0.5990
Apr.	27,296.61	5,490,000	0.4972
May	30,219.99	5,810,000	0.5201
June	29,070.03	6,050,000	0.4805
July	30,651.66	6,710,000	0.4568
Aug.	31,493.16	6,624,000	0.4754
Sept.	31,202.81	6,660,000	0.4685
Oct.	36,520.31	7,793,000	0.4686
Nov.	36,453.37	8,120,000	0.4489
Dec.	40,419.72	8,640,000	0.4678
1930			
Jan.	34,287.55	8,080,000	0.4244
Feb.	30,479.58	6,950,000	0.4386
Mar.	33,916.16	7,250,000	0.4678
Apr.	33,041.77	6,960,000	0.4747
May	33,263.54	7,830,000	0.4248
June	31,963.45	7,470,000	0.4279
July	36,093.84	8,170,000	0.4418
Aug.	38,103.05	8,310,000	0.4585
Sept.	34,410.33	8,050,000	0.4275
Oct.	36,603.95	8,890,000	0.4117
Nov.	33,929.48	8,080,000	0.4199
Dec.	36,695.55	8,936,000	0.4106
1931			
Jan.	40,359.47	9,120,000	0.4425
Feb.	42,184.20	10,850,000	0.3888
Mar.	43,484.40	10,630,000	0.4010
Apr.	37,229.55	8,020,000	0.4642
May	37,567.12	7,930,000	0.4737
June	43,510.48	10,300,000	0.4224
July	45,467.33	10,070,000	0.4515
Aug.	47,740.17	10,730,000	0.4449

be it normal or otherwise, the probability will not exceed 1 divided by the square of the chance assumed. If, for example, the standard error is desired, which is a fifty-fifty chance or, as it may otherwise be said, where the probability is equal that the variation is due to chance or assignable causes, by substitution it is seen that

$$0.5 \geqq 1 - \frac{1}{\lambda^2} \ldots\ldots\ldots\ldots\ldots\ldots [8]$$

whence

$$\lambda = 1.414$$

which is to be compared with the value assumed in a normal distribution of 0.6745. It is seen, therefore, that the band is 2.1 times as wide, and it may definitely be said that, regardless of the form of the distribution, be it normal or otherwise, *at least* 50 per cent of the cases will fall within this band created; i.e., $\pm S\lambda$ on either side of the curve fitted or $\pm 1.414S$. It is highly probable that many more will fall within this band, and if a normal distribution existed, then 50 per cent would fall within the limit of $\pm 0.6745S$. The Tchebycheff inequality is perfectly general and will always apply. However, if the distribution of residuals forms a curve with a single mode whose asymptotes are at infinity, as must be true in this case, it has been shown by Camp[11] that

$$P \geqq 1 - \frac{1}{2.25\lambda^2} \ldots\ldots\ldots\ldots\ldots\ldots [9]$$

In the case under discussion the value of λ then becomes 0.945 where P is 0.5. But by assumption[11] P cannot be less than unity, so that for such a case a value of probable error equal to the standard error would be used.

In this paper the band has been laid out on either side of the marginal-cost equation at a distance equal to the standard error. In using such a band it may then be said that no significance need be attached to any value which falls within the band; that values falling outside the band become increasingly significant as their distance from the band increases; that for any value outside the band there is a greater probability that there is an accountable cause than that the variation is due to chance and hence should point the way for an investigation to determine the cause.

A casual inspection of the width of these bands will give a very interesting and revealing impression of the homogeneity of the data, for the wider the band the less the significance that can be attached to any cost variation from the value as given by the equation.

UNIT VERSUS MARGINAL COSTS

One of the commonest uses of these equations is to determine the price at which additional blocks of output can be taken on. This is found from the marginal-cost equation in which it is assumed that new blocks can be taken on at a value equal to the slope of the line. The assumptions upon which this is based are, first, that there is a cost which is irrespective of the output—the intercept of the curve—and this cost is already part of the plant cost, and second, that there is a constant unit cost at which all future blocks of output should be taken on. This method does not share with the original output any of the savings due to the increased load, nor does it charge to the added load any part of the "fixed operating cost."

[11] B. H. Camp, "A New Generalization of Tchebycheff's Statistical Inequality." Bulletin of the American Mathematical Society, vol. 28 (1922), pp. 427–32. An excellent summary, containing additions and corrections may be found in Camp, "Mathematical Part of Elementary Statistics," Heath and Co., p. 256.

TABLE 2 LEAST-SQUARE SOLUTION FOR THE MARGINAL-COST EQUATION

N	y	x	xy	x^2
1	23.6	4,639	109,480	21,520,300
2	26.9	4,400	118,360	19,360,000
3	30.4	5,080	154,432	25,806,400
4	27.3	5,490	149,877	30,140,100
5	30.2	6,810	175,462	33,756,100
6	29.1	6,050	176,055	36,602,500
7	30.7	6,710	205,997	45,024,100
8	31.5	6,624	208,656	43,877,400
9	31.2	6,660	207,792	44,355,600
10	36.5	7,793	284,445	60,730,800
11	36.5	8,120	296,380	65,934,400
12	40.4	8,640	349,056	74,649,600
13	34.3	8,080	277,144	65,286,400
14	30.5	6,950	211,975	48,302,500
15	33.9	7,250	245,775	52,562,500
16	33.0	6,960	229,680	48,441,600
17	33.3	7,830	260,739	61,308,900
18	32.0	7,470	239,040	55,800,900
19	36.1	8,170	294,937	66,748,900
20	38.1	8,310	316,611	69,056,100
21	34.4	8,050	276,920	64,802,500
22	36.6	8,890	325,374	79,032,100
23	33.9	8,080	273,912	65,286,400
24	36.7	8,936	327,951	79,852,100
25	40.4	9,120	368,448	83,174,400
26	42.2	10,850	457,870	117,722,500
27	43.5	10,630	462,405	112,996,900
28	37.2	8,020	298,344	64,320,400
29	37.6	7,930	298,168	62,884,900
30	43.5	10,300	448,050	106,090,000
31	45.5	10,070	458,185	101,404,900
32	47.7	10,730	511,821	115,132,900
	1,124.7	248,642	9,019,341	2,021,965,100

$$1{,}124.7 = 32A + 248{,}642B$$
$$9{,}019{,}341 = 248{,}642A + 2{,}021{,}965{,}100B$$
$$35.15 = A + 7{,}770 \times B$$
$$\underline{36.27 = A + 8{,}132 \times B}$$
$$1.12 \qquad 362 \times B$$

$$1.12/362 = B = 0.00310$$
$$35.15 = A + 24.09$$
$$A = 11.06$$
$$36.27 = A + 25.21$$
$$A = 11.06$$
$$\text{O.E.} = 11{,}060 + 0.31 \times \text{Kwhr}$$

A materially different answer would be obtained by using the unit-cost curves. In this case the fixed operating cost is properly allocated, and the savings due to increased load are divided among all the blocks of output produced. These two points of view are quite different, and both are proper and can be defended. As a general rule it would seem to be justifiable to charge small additions at the unit cost and large ones at a figure near the marginal cost. As large blocks of output are often obtained only on a competitive basis, the marginal cost is approached, whereas the customers for the smaller blocks do not have the same competitive advantages and it is seldom necessary to cut the price so carefully. Also in the final analysis the cost of production is only part of the delivery cost, and in most cases a small one. Therefore, especially with small units of output, the various other charges such as the distribution, sales, etc., assume greater importance than the cost of the product, and the price is governed by the former rather than by the latter.

This discussion has concerned itself entirely with the limits of application and definitions of terms from a general point of view. The application is illustrated by a determination of the various equations of a steam-generating plant.

A PRACTICAL EXAMPLE

A power-generating station theoretically is operated because by its operation the required power is delivered the most cheaply and the most advantageously to those operating it. The major divisions of the costs of operating a station are two: the operating costs and the fixed costs. This paper will concern itself solely with those costs known as "direct station operating costs." Of these "direct station operating costs" there are four major divisions: labor, fuel, supplies, and maintenance. The particular item chargeable to each one of these is specified in considerable detail by the "Uniform Classification of Accounts," recommended by the National Electric Light

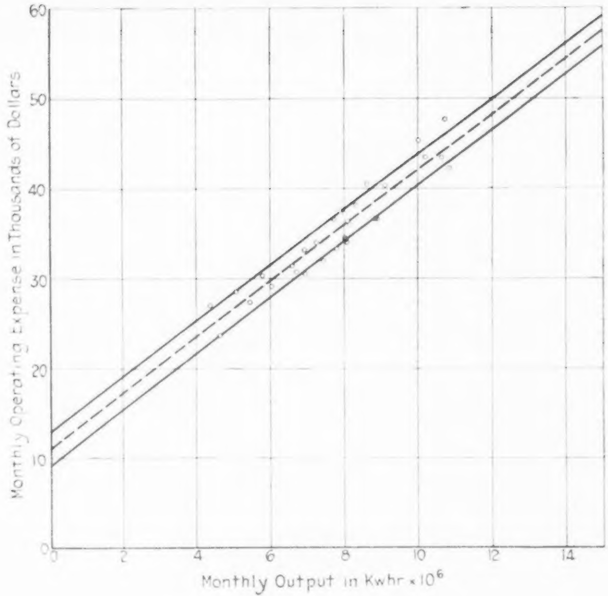


FIG. 5 MARGINAL-COST BAND
(O.E. = \$11,060 + 0.31 ¢. × Kwhr.)

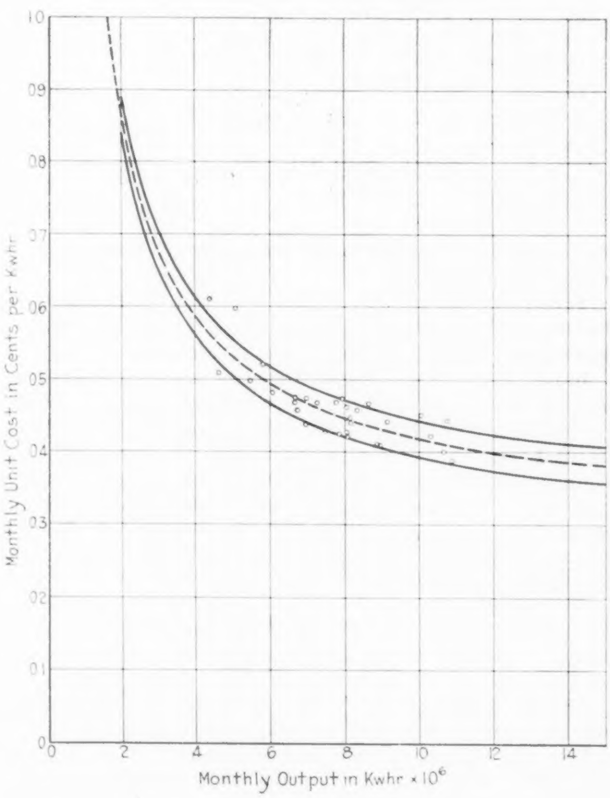


FIG. 6 UNIT-COST BAND
(U.C. = 0.31 ¢. + 11.6/Kwhr in millions.)

TABLE 3 TEST OF SIGNIFICANCE OF THE EQUATION
O.E. = 11,000 + 0.311 × KWHR

	Kwhr	0.311 × kwhr	+ 11,000	Actual	S	S^2	σ	σ^2
1	4,639	14,400	25,400	23,600	+1,800	3,240	+12,500	146,000
2	4,400	13,700	24,700	26,900	−2,200	4,830	+ 8,200	67,000
3	5,080	15,800	26,800	30,400	−3,600	13,000	+ 4,700	22,000
4	5,490	17,100	28,100	27,300	+ 800	640	+ 7,800	60,900
5	5,810	18,100	29,100	30,200	−1,100	1,210	+ 4,900	24,000
6	6,050	18,800	29,800	29,100	+ 700	490	+ 6,000	36,000
7	6,710	20,900	31,900	30,700	+1,200	1,440	+ 4,400	19,300
8	6,624	20,600	31,600	31,500	+ 100	10	+ 3,600	13,000
9	6,660	20,800	31,800	31,200	+ 600	360	+ 3,900	15,200
10	7,793	24,200	35,200	36,500	−1,300	1,690	+ 1,400	1,960
11	8,120	25,300	36,300	36,500	− 200	40	− 1,400	1,960
12	8,640	26,800	37,800	40,400	−2,600	6,740	− 5,300	28,000
13	8,080	25,100	36,100	34,300	+1,800	3,240	+ 800	640
14	6,950	21,600	32,600	30,500	+2,100	4,400	+ 4,600	21,200
15	7,250	22,600	33,600	33,900	− 300	90	+ 1,200	1,440
16	6,960	21,700	32,700	33,000	− 300	90	+ 2,100	4,400
17	7,830	24,300	35,300	33,300	+2,000	4,000	+ 1,800	3,230
18	7,470	23,200	34,200	32,000	+2,200	4,840	+ 3,100	9,600
19	8,170	25,400	36,400	36,100	+ 300	90	− 1,000	1,000
20	8,310	25,900	36,900	38,100	−1,200	1,440	− 3,000	9,000
21	8,050	25,000	36,000	34,400	+1,600	2,560	+ 700	490
22	8,890	27,600	38,600	36,600	+2,000	4,000	− 1,500	2,250
23	8,080	25,100	36,100	33,900	+2,200	4,840	+ 1,200	1,440
24	8,936	27,800	38,800	36,700	+2,100	4,400	− 1,600	2,560
25	9,120	28,400	39,400	40,400	−1,000	1,000	− 5,300	28,000
26	10,850	33,800	44,800	42,200	+2,600	6,740	− 6,100	37,100
27	10,630	33,000	44,000	43,500	+ 500	250	− 8,400	70,250
28	8,020	24,900	35,900	37,200	−1,300	1,690	− 2,100	4,400
29	7,930	24,600	35,600	37,600	−2,000	4,000	− 2,500	6,250
30	10,300	32,000	43,000	43,500	− 500	250	− 8,400	70,250
31	10,070	31,200	42,200	45,500	−3,300	10,850	−10,400	108,000
32	10,730	33,400	44,400	47,700	−3,300	10,850	−12,600	159,000
				1,124,700		103,310,000		975,820,000
				$\epsilon/32$ = 35,100		3,229,000		30,494,000
					$S/32$	1,800		$\sigma/32$ = 5,535

$$r = \sqrt{1 - \frac{3,229,000}{30,494,000}} = \sqrt{1 - 0.106} = \sqrt{0.894} = 0.946 = A+$$

Association and adopted by the Public Service Commission of the State of New York.

The plant under consideration is a modern 450-lb per sq in. bin-type pulverized-coal plant consisting of one 75,000- and one 20,000-kva unit and four boilers situated on tidewater.

In Fig. 4 are plotted the operating expenses and output of the station taken from Table 1. These same costs are plotted against output in Fig. 5 and the unit costs are plotted in Fig. 6. Table 2 presents the calculations for and the solution of the least-square equations. The columns of x, y, and N are set up and the last two columns are obtained by multiplying through successively by x, giving tabular values of xy and x^2. The summation of the columns give the values for the two normal equations; thus,

$$\Sigma y = \Sigma NA + Bx$$

$$\Sigma xy = \Sigma xA + Bx^2$$

The last value of N equals ΣN and the arrangement and solution of these equations are clearly shown in Table 2.

In order to test the significance of an equation each value of y must be calculated from the given value of x and the value thus calculated must be compared with the actual figure. This is illustrated in Table 3 where the equation

$$\text{O.E.} = 11,000 + 0.311 \times \text{Kwhr}$$

is tested. From each calculated value of y is subtracted the actual value, and this deviation, when squared, summed, and the square root taken, gives the standard error. In a similar manner, the average value of $y = 35,100$ is subtracted from the calculated, and by squaring each deviation, summing, and extracting the square root, the standard deviation is obtained. From definition the correlation coefficient is obtained by extracting the square root of the quantity, 1 minus the square of the standard error divided by the square of the standard deviation. In this case the value obtained is 0.946 and by reference to Fig. 3 it is seen that such a value is highly significant.

In a similar manner the equation for the unit cost is tested in Table 4. This equation is obtained from the marginal equation by dividing through by the kilowatt-hours, thus:

$$\text{O.E} = 11,000 + 0.311 \times \text{Kwhr}$$

$$\frac{\text{O.E.}}{\text{Kwhr}} = \frac{11,000}{\text{Kwhr}} + 0.311$$

$$\frac{\text{O.E.}}{\text{Kwhr}} = \text{U.C.}$$

$$\text{U.C.} = 0.311 + 11/\text{Kwhr in millions}$$

The band was obtained by plotting on either side of the curve a similar curve at a distance equal to the standard error which is \$1800 for the marginal-cost equation and 0.000646 for the unit-cost equation. This has been done in Figs. 5 and 6, respectively.

As originally stated, therefore, it has been shown how the best straight-line relationship between operating costs and output may be determined by the method of least squares. The significance of the fit of the equation has been determined and the control band established, while the unit-cost curve, with its band and its test of significance, has also been presented.

This method of analysis shows first how to determine the marginal-cost and unit-cost equations so that the probable results of operation under different conditions than exist may be estimated and the probable accuracy of such estimates can be determined. Second, it is shown how close control of station operation may be had by the use of control bands, fitted at a predetermined and known distance, giving a definite probability of assignable causal variation. As managerial guides these control bands are invaluable, as the station operators may be justifiably praised or blamed as the case may be.

USE OF THE CURVES

The use of the unit-cost curve as a managerial guide is illustrated by a consideration of the points 5 080,000 kwhr and the unit cost 0.598 cent per kwhr, for the month of March, 1929, and of 10,730,000 kwhr and the unit cost 0.445, which is for the month of August, 1931. (See Figs. 4, 5, and 6.) In both these cases the unit cost is high. In the first case it should be only about 0.55, and in the second, about 0.41. Reference to the plant operating sheets shows that in March, 1929, the item of boiler-accessory maintenance was about \$2000 higher than the previous average, while in August, 1931, the item of maintenance of furnaces and boilers was around \$1500 higher than the average. This immediately shows that an investigation of these items is necessary, and even more particularly shows up the variability of the maintenance accounts.

The use of such methods is not limited to station operating costs, nor for that matter to costs, but is applicable to a wide variety of problems. Sometimes cost data do not immediately

yield themselves to such analysis, in which case the physical units may be attacked in a similar manner; this, then, will indicate whether the accounts have been properly kept, will clearly show whether there have been alterations in price level, and in fact prove most illuminating.

There is nothing inherently new in the method here presented, but it is believed that the procedure will be of interest to the engineering world. Fitting lines to data is familiar to all engineers, but it is always best to have a definite technique which will always yield the same answer, no matter who applies it, as the method of least squares does, rather than to fit a curve by eye and depend upon experience or judgment for the excellence of the fit. The use of probable error and other statistical terms and methods is, of course, familiar to all statisticians, but the application of these methods to a specific problem of engineering economics and particularly the use of a control band is not such familiar engineering technique.

TABLE 4 (*Right*) TEST OF SIGNIFICANCE OF THE EQUATION U.C. = 0.31 + 11.06/KWHR IN MILLIONS

			Unit cost					
	Kwhr	Actual	Actual	Comp.	S	S^2	σ	σ^2
1	4,639	23,600	0.5098	0.5482	+0.0384	0.0015	+0.0498	0.0025
2	4,400	26,900	0.6105	0.5611	−0.0494	0.0024	+0.1505	0.0227
3	5,080	30,400	0.5990	0.5276	−0.0714	0.0051	+0.1390	0.0193
4	5,490	27,300	0.4972	0.5115	+0.0143	0.0002	+0.0372	0.0014
5	5,810	30,200	0.5201	0.5004	−0.0197	0.0004	+0.0601	0.0036
6	6,050	29,100	0.4805	0.4929	+0.0124	0.0002	+0.0205	0.0004
7	6,710	30,700	0.4568	0.4750	+0.0182	0.0003	−0.0032	....
8	6,624	31,500	0.4754	0.4772	+0.0018	....	+0.0154	0.0002
9	6,660	31,200	0.4685	0.4763	+0.0078	0.0001	+0.0085	0.0001
10	7,793	36,500	0.4686	0.4523	−0.0163	0.0003	+0.0086	0.0001
11	8,120	36,500	0.4489	0.4466	−0.0023	....	−0.0111	0.0001
12	8,640	40,400	0.4678	0.4384	−0.0294	0.0009	+0.0078	0.0001
13	8,080	34,300	0.4244	0.4472	+0.0228	0.0005	−0.0356	0.0013
14	6,950	30,500	0.4386	0.4694	+0.0308	0.0009	−0.0214	0.0005
15	7,250	33,900	0.4678	0.4628	−0.0050	....	+0.0078	0.0001
16	6,960	33,000	0.4747	0.4691	−0.0056	....	+0.0147	0.0002
17	7,830	33,300	0.4248	0.4516	+0.0268	0.0007	−0.0352	0.0012
18	7,470	32,000	0.4279	0.4584	+0.0305	0.0009	−0.0321	0.0010
19	8,170	36,100	0.4418	0.4457	+0.0039	....	−0.0182	0.0003
20	8,310	38,100	0.4585	0.4435	−0.0150	0.0002	−0.0015	....
21	8,050	34,400	0.4275	0.4477	+0.0202	0.0004	−0.0325	0.0011
22	8,890	36,600	0.4117	0.4348	+0.0231	0.0005	−0.0483	0.0023
23	8,080	33,900	0.4199	0.4472	+0.0293	0.0008	−0.0401	0.0016
24	8,936	36,700	0.4106	0.4342	+0.0236	0.0006	−0.0494	0.0024
25	9,120	40,400	0.4425	0.4317	−0.0118	0.0001	−0.0175	0.0003
26	10,850	42,200	0.3888	0.4125	+0.0237	0.0006	−0.0712	0.0051
27	10,630	43,500	0.4010	0.4146	+0.0136	0.0002	−0.0590	0.0035
28	8,020	37,200	0.4642	0.4483	−0.0159	0.0003	+0.0042	....
29	7,930	37,600	0.4737	0.4498	−0.0239	0.0006	+0.0137	0.0002
30	10,300	43,500	0.4224	0.4179	−0.0045	....	−0.0376	0.0014
31	10,070	45,500	0.4515	0.4203	−0.0312	0.0010	−0.0085	0.0001
32	10,730	47,700	0.4449	0.4136	−0.0313	0.0010	−0.0151	0.0002
		1,124,700	14.7203			0.0207		0.0733
		35,100	4.600			0.000646		0.002291

$$r = \sqrt{1 - \frac{0.000646}{0.002291}} = 0.8473; \quad S/N = 0.0254; \quad \sigma = 0.048$$

Richard Arkwright

(*Continued from page 684*)

have to face a slackening of the rate of further industrial expansion. It is true that during all previous depressions predictions were made that the zenith of industrial expansion had been reached and every time the gloomy prophets have been utterly discredited by a new wave of optimism, invariably caused by some unforeseen event. The possibility exists, of course, that something similar might happen this time, although at present there is nothing to indicate its approach. The impending important developments in the chemical industry, as, for instance, the manufacture of synthetic gasoline, sugar, and feed for cattle from cheap raw materials, might supply a much-needed stimulus, although it seems more probable that these products, competing with existing commodities, will introduce serious dislocations and complexities into our already strained economic system.

Industrial expansion presupposes expanding markets, whereas it is impossible to close one's eyes to the fact that forces are at work tending to contract them. These forces, which are by no means identical with the causes of the present industrial depression and financial crisis, are manifold: economic, political, psychological. It will be sufficient to mention here only some of the more obvious: the existence of industrial plant, means of transportation, and land under cultivation more than ample to supply all reasonable and at present known wants in domestic and foreign markets; the steadily increasing efficiency of existing equipment caused by improved methods of management; and economic nationalism aiming at self-sufficiency and strangling international trade.

To counteract these influences it will be necessary to find a way to raise the level and increase the scope of domestic buying power and to strengthen the feeling of individual economic security. Unless this is done, it seems probable that, even after the return of more normal business conditions, our industry, especially the enterprises manufacturing producers' goods, will have to undergo a process of retrenchment and adaptation to changing world conditions. This process will necessarily involve a great deal of suffering and painful readjustments, particularly if the events are allowed to run their natural course uncontrolled by organized collective intelligence and forethought and the guiding hand of enlightened statesmanship.

MECHANICAL ENGINEERING

Vol. 54 OCTOBER, 1932 No. 10

GEORGE A. STETSON, *Editor*

What Does Pearl Street Mean?

FIFTY years ago the world jogged along quite complacently without electrical power. But the restless spirit of Thos. A. Edison was at work contriving a complete system of generation, distribution, and use of electrical energy for lighting and power that was destined to provide the world with one of the most useful services it had ever known. Today the numerous and gigantic progeny of the Pearl Street Station, the Fiftieth Anniversary of whose opening was recently celebrated in New York, provide a network of electricity supply that extends to almost every place where civilized men live and labor.

It is important to remember that Edison's gift to mankind was a product of individual initiative and industry. Edison saw the opportunity and seized it under the powerful stimulus of the promise of those rewards, material and intangible, that come to men of his ability and attainments. It is also significant that his work was conceived and has prospered most effectively in a country where the opportunity and the rewards were greatest, and where there existed an environment in which individual initiative and industry were encouraged and could flourish.

What a striking contrast is observed when the beginning of this half-century of electricity is viewed in the light of the present day. Edison supplied something absolutely new and unique, something the world had got along without since the beginning of time, something which practically no one had sufficient knowledge or imagination even to wish for. Today, few are getting along without it, and those few are eager to engage this tireless, competent, inexpensive, and versatile servant. What was the fruit of one man's genius and industry has taken its place with the indispensable necessities of life, and, in the minds of many, is being looked upon as a God-given, inalienable right, a public resource.

Small wonder that social, economic, and political problems follow in the wake of such a triumphant conqueror. Some one has aptly termed ours a power-sustained world. Today the principal element of this sustenance is electricity. Take it away and we perish, or revert to a much lower standard of living. Here is an element, therefore, so profoundly important to our welfare that it cannot be extricated from the culture and life of our times, from the innumerable details of the conveniences and services upon which we continuously depend, or from the basic philosophy according to which our individual and public institutions are developed.

This example of our dependence upon man-made things and services is but one of a long list of human discoveries of which the material structure of civilization is composed. The unknown and the unessential become the ubiquitous and the necessary. Tools, weapons, fire, shelter, clothing, writing and printing, transportation by water, land, and air, communication, the division of labor, machinery and machine-production methods, medicine and surgery, sanitation, education, religious and political institutions, trade and commerce, science and engineering in impressive array bear evidence of our evolution from the brute, who leaves nature as he finds it.

As time goes on science will contribute other unknown elements of progress upon which the world will become dependent. What we need is a generous perspective, a constructive imagination, and an adaptable and tolerant philosophy of human welfare and progress that will permit the assimilation of these new elements of civilization with a maximum of benefit and a minimum of destructive disturbance. As a group capable of doing in lesser ways what Edison did, engineers particularly should have this larger vision.

Good Luck or Hard Work?

ENGINEERING materials are subject to the same laws of supply and demand that control our entire economic system, except that the demand can be created or fostered in ways which differ somewhat in detail but are essentially the same in substance as those affecting all other materials. Two examples will illustrate what is meant.

During the World War there was a demand for lead for bullets. This brought about an increase in the production of lead, as well as material improvements in the—up to then—somewhat primitive science of metallurgy of lead. When peace was declared, however, the demand for lead fell off. About this time, the electric starter became an essential part of the modern automobile, and this device required storage batteries. Here was a market for lead that the lead industry did little or nothing to develop. Next came the radio, which in its early forms needed a storage battery. Thus the battery business provided profits for the lead-mining industry until, with the development of the all-electric radio, the demand for batteries fell off. Is the lead industry doing anything to develop other uses of lead?

Another "war baby" was nickel. While this metal was used on a comparatively small scale in making special steels such as those used for automobile crank-shafts and the like, its main market lay in armor plate. The cessation of hostilities promised to affect the nickel industry materially, but it vigorously developed peace-time uses, both for the metal itself and its alloy with copper, known as Monel metal, which could be produced directly from the ores. Thousands of uses have been developed, from boiler plate made up of a heavy layer

of plain steel and a thin layer of nickel steel, to equipment for cafeterias and restaurants, with the result that the industry has been placed on a firm basis and is no longer dependent on war uses.

Thus in some cases it has been luck which has opened new vistas to existing industries. In others, of which nickel is an example, it has been hard work. Perhaps if more of that latter were applied, industries other than the nickel would find relief if not salvation.

The Naval Academy Curriculum

CHANGES in the curriculum at the United States Naval Academy recently announced in the papers indicate an increase from 21.6 to 31.6 per cent in the time devoted to cultural subjects, a reduction from 33.6 to 31.2 per cent in the time spent on mathematics and the pure and applied sciences, and also a reduction from 44.8 to 37.2 per cent in the time given over to professional subjects. These changes, says the announcement, are in line with recent trends in engineering education throughout the country, and were prompted by what "seemed to be a realization that high executive positions were tending to be filled by others than engineers, and that the reason lay in the fact that such individuals showed better and broader leadership qualities than did the more narrowly educated technicians." In line with the liberalizing objectives of the changes in curriculum, an entirely new department of economics and government has been set up.

The adoption of a policy of liberalizing the curriculum to devote more time to such cultural subjects as history, literature, economics, and government is commendable and a step in the right direction. It cannot be assumed, and undoubtedly the officers of the Naval Academy do not assume, that a mere shifting of hours from technical to non-technical or "cultural" subjects will produce qualities of leadership where none is latent, or that the sciences are not cultural studies. But inasmuch as confusion on these points probably does exist, because of the varied meanings that are attached to words in common usage, some comments on these statements may not be amiss.

Education organizes and develops abilities that are inherent in individuals. It does not provide qualities of character that are lacking or are meagerly possessed. If engineering graduates fail to develop as leaders, the difficulty is primarily with the graduates themselves and not with a system of education. Changes in curriculum may provide these graduates with better training and more potent equipment with which to exercise their natural abilities, and undoubtedly smooth the roadway to success over which all must travel, but they will not make up for a fundamental omission of qualities of leadership from a man's character.

Examination of the engineering profession, however, tends to show that an engineering education has been, in the past at least, a successful preliminary to success in positions where certain qualities of leadership are essential. Statistics have proved, for example, that more than two-thirds of the graduates of engineering colleges eventually find themselves performing administrative and managerial functions. While this is not leadership in its broadest sense, it indicates either that men having qualifications for such positions chose engineering courses and succeeded in spite of their narrowly technical content, or that there is some essential discipline in engineering education that bears fruit later on. The modern tendency to recognize this ultimate executive function of engineering graduates by liberalizing the curriculum has been in progress for several years. A most keenly critical analysis of it was made by Prof. R. E. Doherty, of Yale University, in a paper read before the American Institute of Electrical Engineers at its Cleveland meeting, June, 1932, and published in the July issue of *Electrical Engineering*. Professor Doherty's paper is hereby commended to the attention of all engineers interested in education.

That the sciences are themselves cultural subjects may not need demonstration. Certainly in the culture of today the sciences have a place of increasing importance. A knowledge of them can scarcely be avoided by persons living in modern civilized communities. They invade the primary-school room and the newspaper. The commonest elements of daily life and intercourse proclaim them. They jostle older gods of mysticism and superstition, and give assistance and greater scope to the arts. If culture be the training and refinement of the mind, it is obvious that the discipline of the sciences as the very quintessence of rationality is truly cultural. The difficulty, perhaps, is not that the sciences are non-cultural but that those who profess and study them fail to integrate them properly into their own lives and into the meaning of life and human experience. When this is accomplished the sciences will serve educational ends as truly as those more deeply but more vaguely sensed verities that persist in literature, art, and history, and from which the present age draws so much inspiration.

Engineering education owes a lasting debt of gratitude to the Naval Academy for providing it with some teachers of exceptional merit and influence. Robert Henry Thurston, sometime instructor at the Academy, first president of the A.S.M.E., professor at Stevens Institute of Technology and Sibley College, Cornell University, one who brought the spirit and method of science to engineering; Ira Nelson Hollis, professor at Harvard and later President of Worcester Polytechnic Institute, whose death cut short a valuable study of the philosophy and history of engineering; Mortimer Elwyn Cooley, for many years dean of engineering at the University of Michigan, an appraisal engineer of high authority; and William Frederick Durand, professor at Michigan State Agricultural School, Cornell University, and later at Leland Stanford University, author, eloquent speaker, and expert in hydraulics and aerodynamics; represent but four of these Naval Academy products who became presidents of the A.S.M.E. Should the Academy be successful in producing more men of such caliber by whatever curriculum, the engineering profession and the world at large will be even more deeply in debt to it.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AIR ENGINEERING

The Flow of Air Through Circular Orifices in Thin Plates

THE purpose of this investigation was to verify and extend the range of existing data on the flow of air through square-edged circular orifices in thin plates. The weighing-tank method previously described in another bulletin (No. 207) was used in determining the weight of air flowing through the orifices. The coefficients of discharge were determined for the orifices for inlet pressures up to 10 in. of water when placed in a Durley box, and for inlet pressures up to 35 in. of water and also up to 35 in. of mercury when placed in the orifice tank. No attempt was made to control the temperature, which varied slightly from room temperature. The derivation of Durley's equation is given in the original article, together with a comparison with Fliegner's equation. No orifices larger than $2^1/_2$ in. were used. The following conclusions are drawn from this investigation:

The coefficients of discharge through square-edged orifices in thin plates increase in value with an increase in inlet pressure up to the critical pressure, when the coefficient is based on Durley's equations; that is, the coefficient is the ratio of the weight of air actually discharged to the weight that would be discharged when computed by Durley's equation.

The plotted values of the coefficients for orifices of various diameters show that all have the same general slope, increasing with increased inlet pressure. Within the range of orifice diameters and pressures used in these tests, all coefficients might be represented by a single line such that its values would be within 1 per cent of the values actually found. For work in which a tolerance of 1 per cent is permissible, this arrangement would simplify the calculations.

The difference between the slope of the coefficient curves given by Durley and those found in these tests may be due to the different methods used in determining the weight of air discharged. For the range of pressures used by Durley the difference is quite small.

Square-edged orifices should be very carefully used and preserved. Very slight injury to the entrance edge may cause a change in the coefficient of from 2 to 3 per cent, which may not be detected until the orifice is recalibrated. (Jos. A. Polson and Jos. G. Lowther, in *University of Illinois Bulletin*, vol. 29, no. 44, Jan. 29, 1932; the same publication is also listed as Bulletin No. 240, Engineering Experiment Station, pp. 5–37, 14 figs., *e*)

APPLIED MECHANICS (See also Air Engineering: The Flow of Air Through Circular Orifices in Thin Plates)

Action of Gravity on Belts—The Lewis Effect

WILFRED LEWIS in his paper before The American Society of Mechanical Engineers (*Transactions*, vol. 7, 1886, p. 549) has shown that the sum of the tensions on both sides of the pulley is not a constant, but increases with the load. Since this discovery of Lewis there have been a number of attempts to explain why this happens. Kretz and other investigators have attempted to prove mathematically the Lewis effect, but apparently have not been successful. In 1894 Friedmann showed that the catenaries of the tight and slack sides of the belt had different parameters for the belt in motion and the belt at rest. In 1896 Schultze-Pillot published a new theory of belts based on Friedmann's observation, but this again did not take into proper consideration certain factors. In 1928 Doctor Swift attempted to explain the Lewis effect on the basis of variation of specific stretch with the tension; he points out, however, that this explanation is not sufficient to account for the fact that for the same tension the power transmitted by a horizontal belt is markedly greater than that transmitted by a vertical belt, and that in the former case the power transmitted increases with the distance of the pulleys from each other. It is to explain these empirical facts as well as the Lewis effect that Swift brings in the action of gravity. In this way he establishes a relation between the tensions on the slack and tight sides of the belt and the stretching of the belt, without, however, taking into consideration the influence of the velocity on the parameter of the catenary formed by the belt. What the present article attempts to do is to prove that the Swift equation is correct for the effect observed by Friedmann. This is done by an analytical method imitating that used by Kretz. After obtaining the corrected equation, the author modifies it in order to obtain a simple and general geometric construction which gives directly the magnitude of the Lewis effect, and then proceeds to prove it by experiment. The article is extensive and can be abstracted only in part.

The author starts by deriving equations in accordance with Friedmann's work to determine the shape and tension at various points of a running belt. He starts with the statement that the two sides of the belt connecting two pulleys of a running transmission generally execute oscillations about an average line having the shape of a catenary, the parameter of which differs from the parameter of a stationary belt by a term due to the action of the centrifugal force. He gives an expression for the parameter of the catenary $a = T'/p$, where T' is the dynamic tension equal to the real tension less the term expressing the centrifugal force, pv^2/g, the rôle of which becomes particularly important at high loads and low tension of the slack belt; p is the weight of a unit of length of the belt. Numerical values for a certain example are given in the original article.

He proceeds next to the determination of the influence of the weight of the belt on the arc of contact with the pulley and the lengths of the sides of the belt. Let it be assumed that we have two pulleys, Fig. 1 (Fig. 2 of the original), the axes of which are in the same horizontal plane. A_1, B_1 are the points of contact of a common upper tangent. A_2, B_2 are the points of contact of a similar lower tangent. Because of the bending of the belt under the action of its weight, the leading and trailing sides do not touch the pulley at the points A_1, B_1, but at A'_1, B'_1, which are nearer to each other than A_1, B_1, while on the lower side the real points of contact are A'_2, B'_2, which

are farther apart than A_2, B_2, this again being due to the effect of weight. Without material error, we can write for arc $AA_1 = R\varphi_1$ the following expressions:

$$A_1A'_1 = R \tan \varphi_1 = R \frac{s_1}{a}$$

Here φ is the angle equal to that made by the tangent at the point of contact with the horizontal; s_1 is half the length

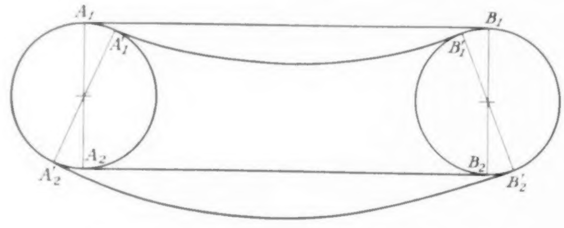


FIG. 1 DIAGRAM SHOWING FORCES ACTING ON BELTS
(Fig. 2 of the original.)

of the arc of the catenary between the pulleys, and in the first approximation may be confused with the length A_1B_1 of the common tangent or with the distance between the axes. If we designate by T'_1 and T'_2 the dynamic tension of the lower and upper sides of the belt and by R and r the radii of the pulleys, we obtain:

$$A_1A'_1 = \frac{RD}{2T'_1} p \qquad B_1B'_1 = \frac{rD}{2T'_1} p$$

$$A_2A'_2 = \frac{2T'_2}{RD} p \qquad B_2B'_2 = \frac{rD}{2T'_2} p$$

If the slack side is on top, the arc of contact of the belt with the pulley increases when we pass from action at no load to action at full load, this increase being equal to the arc

$$\frac{Dp}{2}\left(\frac{1}{T'_1} - \frac{1}{T'_2}\right)$$

It decreases by the same amount if the slack side of the belt is at the bottom, and this explains why, as is known to practical engineers, when the slack side is on top, the belt will transmit without slipping a greater amount of power than with the slack side at the bottom, and this difference is the greater, the greater the distance between the axes of the pulleys, the heavier the belt, and the lower the static tension.

Length of Tight and Slack Sides Under Load and When Running Idle. The lengths of the two sides of the belt can be deduced analytically from the properties of the catenary, and the original article gives the proper formulas, as well as an expression for the length of arc of contact of the belt on each of the pulleys. As regards the general relation between the tensions under load and at no load, the author gives the following expression:

$$\Lambda_1 = \frac{L_1}{1 + l_1} = L_1(1 - l_1)$$

where L_1 is the natural length of the side of the belt, Λ_1 is the length which it takes under zero tension, and l_1 is the specific elongation of the belt, which means the elongation of a unit of length of belt when the tension therein varies from zero to T_1.

The author proceeds next to the consideration of a neutral layer of the belt—that is, the part that passes over the pulley without change of length. If this neutral layer is at a distance Δ from the pulley, its distance from the axis of rotation is $R_1 = R + \Delta$. The author uses here the length of arc of contact as if it were the same as the length of the neutral layer. He then calls the "total length of the belt" the length of this neutral layer, which is clearly defined in all the belts, no matter how thick they may be. He assumes next that both under load and at no load the natural length of this neutral layer retains the same value. On the assumption that in all belt transmissions the arc of contact is always very small as compared with the length of the side of the belt, it may be admitted that the natural length of the layer is equal to its real value multiplied by $\left(1 - \frac{l_1 + l_2}{2}\right)$, as if the average tension were the average of the tensions on the tight and slack sides, l_1 and l_2 being the specific elongations of the two sides of the belt when the tensions are T_1 and T_2. This may be expressed by the following equation:

$$D\left[2 - l_1 - l_2\right] + \frac{D^3p^2}{24}\left[\frac{1}{T'^2_1} + \frac{1}{T'^2_2}\right] + 2\pi R'\left(1 - \frac{l_1 + l_2}{2}\right)$$
$$= 2D\left[1 - l_0 + \frac{D^2p^2}{24\,T'^2_0}\right] + 2\pi R'(1 - l_0)$$

where only the terms containing ϵ and $\frac{D^3p^2}{24\,T'^2}$ are used, while their product is neglected; and from this the following equation is derived, substituting μ for $\frac{\pi R'}{D}$:

$$\frac{D^2p^2}{24}\left[\frac{1}{T'^2_1} + \frac{1}{T'^2_2} - \frac{2}{T'^2_0}\right] = (1 + \mu)[l_1 + l_2 - 2l_0]$$

The same equations, with proper modifications indicated in the original article, are applicable to the case where the pulleys are not of the same diameter. When the centrifugal force becomes negligible, the Swift equation is obtained, again in terms of the specific elongations. The original article shows next how the Swift equation may be corrected for the effect of centrifugal force. Swift draws certain curves. The present author draws a similar curve for the specific elongation and also for $1/T$, which differs from the Swift curve in that the abscissa T corresponds not to the ordinate $1/T$, but to the dynamic tension $T - (pv^2/g)$, which really amounts to shifting Swift's equilateral hyperbola parallel to the axis T the distance $(pv^2)/g$. This is shown in Fig. 3, while the original Swift curve is shown in Fig. 2. In the curve in Fig. 3, instead of A_2B_2, $A'_2B'_2$ is made to correspond to AB.

Since the factor $\dfrac{1 + \frac{\pi R'}{D}}{D^2p^2}$ depends on the specific weight of the belt, the distance between the axes of the pulleys (the center distances of the pulleys), and the radii of the pulleys, this method of constructing the curve $1/T$ evidently presupposes that the scale of the curve must be adapted to each of the transmissions investigated, and hence requires that one of the two curves should be drawn for each case investigated.

From this the author proceeds to a derivation of a new expression for the Lewis effect. It is claimed that in the new method the only thing that is required is to draw a straight line cutting a curve which is the same in every case.

The specific elongations l_1, l_2, and l_0 may be written as follows:

$$l_1 = \frac{T_1}{\sigma E_1}, \qquad l_2 = \frac{T_2}{\sigma E_2}, \qquad l_0 = \frac{T_0}{\sigma E_0},$$

where E_1, E_2, and E_0 are the moduli of elasticity corresponding

to the tensions T_1, T_2, and T_0, σ being the sectional area of the belt. The equation for the tension becomes, therefore:

$$\frac{D_2p_2}{24}\left(\frac{1}{T'^2_1}+\frac{1}{T'^2_2}-\frac{2}{T'^2_0}\right)=\frac{(1+\mu)}{\sigma}\left(\frac{T_1}{E_1}+\frac{T_2}{E_2}-\frac{2T_0}{E_0}\right)\quad[1]$$

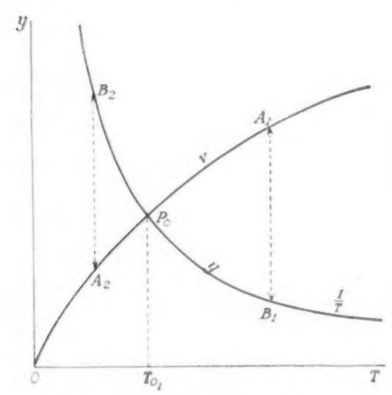


FIG. 2 SWIFT'S CURVE OF SPECIFIC ELONGATIONS IN A BELT
(Fig. 4 of the original.)

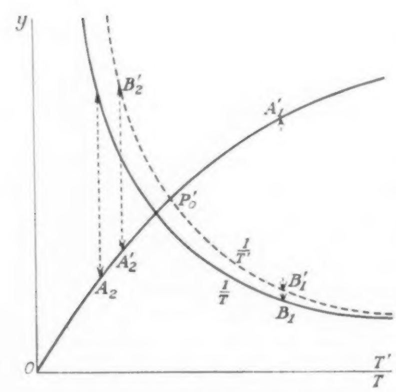


FIG. 3 THE AUTHOR'S MODIFICATION OF SWIFT'S CURVE
(Fig. 5 of the original.)

Let us set $T_1 + T_2 = 2S$, $T'_1 + T'_2 = 2S'$, $T_1 - T_2 = 2Q$, $T'_1 - T'_2 = 2Q$, from which it follows that $T_1 = S + Q$; $T'_1 = S' + Q$; $T_2 = S - Q$; $T'_2 = S' - Q$.

It may be remarked in addition that for all practical purposes $\frac{1}{E_1}+\frac{1}{E_2}=\frac{2}{E_0}$, and further that the product $Q\left[\frac{1}{E_1}-\frac{1}{E_2}\right]$ is essentially negative, because if $T_1 > T_2$ and $Q > 0$, then $\frac{1}{E_1}<\frac{1}{E_2}$, and vice versa. Hence, if we consider only the absolute values of Q and b, of which the definition is given later, and write:

$$A'=\frac{D^2p^2}{24(1+\mu)},$$

$$A=\frac{D^2p^2\sigma E_0}{24(1+\mu)}$$

$$=A'E_0\sigma=A'\frac{T_c}{l_0},$$

$$b=\left(\frac{E_0}{E_1}-\frac{E_0}{E_2}\right)\times\frac{1}{2+2\mu},\ \frac{S'}{Q}=x,\ \frac{T'_0}{Q}=x_0,\ a=x_0+b$$

and then multiply by Q^3/A, Equation [1] becomes:

$$\frac{x^2+1}{(x^2-1)^2}-\frac{1}{x_0^2}=\frac{Q^3}{A}\left(x-a\right)\ldots\ldots\ldots\ldots[2]$$

and we can write

$$u=\frac{x^2+1}{(x^2-1)^2},\quad v=\frac{Q^3}{A}\left(x-a\right)+\frac{1}{x_0^2}\ldots\ldots[3]$$

In this equation u does not depend on the dimensions and characteristics of the transmission, while v alone does so depend. If we plot the curve u and the straight line v, using two rectangular axes with x for abscissas and u or v for ordinates, the equation for the tension becomes located at the point of intersection of the straight line v with the curve u. If x is the abscissa at the point, the following equation is obtained, which expresses the Lewis effect:

$$S-T_0=S'-T'_0=(x-x_0)Q\ldots\ldots\ldots[4]$$

The increase in average tension of the two sides of the belt is therefore equal to the product of half the load multiplied by the difference $x - x_0$ of the abscissas x at the point of intersection of the curves u and v and of the ratio x_0 of the dynamic tension of the slack side to one-half the power transmitted.

The graphic method permits studying the variation of the Lewis effect with the changes in the various factors which affect it. Because of lack of space this part of the article cannot be abstracted as completely as would be desired. The author investigates analytically the variation of the Lewis effect with the character of the transmission. As to the elastic effect, he finds that for the same load the elastic effect b decreases when E_0 increases—that is, when the static tension increases. For a given static tension, b increases very nearly in direct ratio to the load, becoming the greater the smaller the static tension, and in lesser ratio, becoming greater as the center distance between the pulleys increases and the diameter of the pulleys decreases. As regards the action of gravity, he finds that for a given load the action of gravity increases the

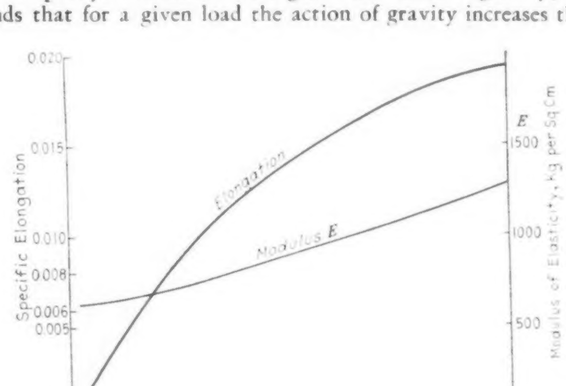


FIG. 4 SKUTSCH'S CURVE OF EXTENSION OF A BELT
(Fig. 8 of the original.)

average tension, the more so the less extensible the belt may be and the greater the center distance of the pulleys. He also investigates the influence of the linear velocity of the pulleys on the Lewis effect and finds that as the linear velocity of the belt increases the elastic effect retains its value, but the effect of gravity increases.

An interesting part of the article consists of the quantitative verification of the theory on the basis of the experiments made by Lewis. Lewis measured on one hand the sum $T + t$ of the tensions of the two sides of the belt and the difference $T - t$, both under load and at no load, as well as the sliding and the arc of contact of the belt with the pulleys. The present author considers particularly the series of experiments made with a leather belt weighing 7.3 kg for a length of 10.3 m, 140 mm wide, and 5.5 mm thick. In what follows metric units are used throughout. The length of the arc of contact of the belt with the pulley is $\pi D = 0.508 \times 3.1416 = 1.60$ m The center distance of the pulleys is therefore $L = \frac{10.30 - 1.60}{2} = 4.35$ m. Hence $\mu = \frac{\pi \times 0.508}{4.35} = 0.2$; p, the weight per meter, is equal to $\frac{7.3}{10.3} = 0.71$ kg, and the section is equal to $14 \times 0.55 = 7.70$ cm², so that $\frac{v^2p}{g} = \frac{4.3^2}{9.8} \times 0.7 = 1.3$ kg.

If we write $A = A' \frac{T_0}{l_0}$, we obtain $A' = \frac{4.35^2 \times 0.71^2}{2' \times 120} = 0.33$, which has the same value in all the tests made with the same belt. The curve of extension is not given, and the author assumes that it does not materially differ from that given by Skutsch, which he reproduces in the original article as Fig. 8 (Fig. 4 in the present abstract); the specific elongation of the latter is shown in the ordinates as a function of the tension per square centimeter of the section of the belt. He gives detailed calculations covering Lewis's test No. 21, all the calculations being made with the slide rule only. In this test it is stated that with a static tension of 200 lb and for a load $T - t$ of 200 lb, the value of $T + t$ is 260 lb, which means an increase of 60 lb under the load of 200 lb with the slip equal to 2.6 per cent. As a pound is equal to 0.454 kg, these values in kilograms become as follows: $T + t = 118$ kg, $T - t = 91$ kg, $2T_0 = 91$ kg, $T = 104$, $t = 13.6$, $Q = 45.5$, $T_0 = 45.5$ kg, $T'_0 = 45.5 - 1.3 = 44.2$ kg, $\frac{T}{\sigma} = \frac{104}{7.7} = 13.5$, $\frac{t}{\sigma} = 1.76$, $\frac{T_0}{\sigma} = 5.8$.

The following values are taken from the curve of specific elongations and of moduli:

$$E_T = 910 \text{ kg}; \quad E_t = 580 \text{ kg}; \quad E_0 = 700; \quad l_0 = 8.5 \times 10^{-3}$$

$$A = 0.33 \times \frac{45.5}{8.5} 10^3 = 1750; \quad \frac{Q^3}{100\,A} = \frac{(45.5)^3}{100 \times 1750} = 0.53$$

$$b = \left(\frac{700}{580} - \frac{700}{910}\right) \frac{1}{2.4} = 0.185$$

$$x_0 = \frac{T'_0}{Q} = \frac{44.1}{45.4} = 0.98; \quad \frac{1}{100 \times x_0^2} = 0.01$$

$$a = 0.98 + 0.185 = 1.165$$

The straight line $v = 0.53\,(x - a) + 0.0104$, passes through the points

$$x = a = 1.165 \qquad v = 0.01$$

$$x = \frac{a}{2} = 0.582 \qquad v = -0.53 \times 0.58 + 0.01 = -0.30$$

It intersects the curve u at the abscissa $x = 1.28$. Hence

$$x - x_0 = 1.28 - 0.98 = -0.30$$

$$T + t - 2T_0 = 0.30 \times 91 = 27 \text{ kg}$$

The Lewis test gives $118 - 91 = 26$ kg. (These figures are taken from the original article, although obviously $118 - 91 = 27$ kg.)

Several other Lewis tests are briefly treated.

The final section of the article deals with tests carried out by the author for the purpose of verification of his theory. He found that his tests are in accord both with the Lewis test and with his theory. (R. Swyngedauw, Professor, Faculty of Sciences, Lille, France, in *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, vol. 131, no. 3, March, 1932, pp. 197–216, *meA*)

ENGINEERING MATERIALS

Strength of Light I-Beams

ROLLED I-beams of standard section have been extensively used in steel structures, and their strength and properties have been determined by tests as well as by actual use. Within recent years the Bethlehem Steel Company and the United States Steel Corporation have rolled I-beams of heavy section having thick webs and flanges; and the Jones & Laughlin Steel Corporation has rolled very light steel beams with weights about one-third of the weights of standard steel beams of the same depth, and having thin webs and flanges. The new heavy-weight and very light-weight I-beams are entirely outside the limits for which tests have been made on standard I-beams, and therefore call for additional tests and investigations. The tests recorded in this bulletin were made to supply fundamental data for the design of light-weight I-beams. The properties of the light-weight I-beams known as J & L Junior beams are compared with the strength of standard beams as summarized by Moore and by Moore and Wilson. By comparing the action of the light J & L Junior beams with the known action of standard beams, it will be possible to draw conclusions for the proper design of light I-beams.

The results show that there was an apparent slight residual deflection after the first series of loads, but that there was no appreciable residual deflection after the second series of loads. However, since in a number of cases the residual deflection was a negative quantity, meaning that the beam recovered an amount greater than the deflection, it will be evident that the cause of the difference must be found in the loading and weighing apparatus. This is due to the difficulty in unloading a beam so as to retain the exact load that was on it at the start of a test, especially when the initial load is small compared with the capacity of the testing machine. This was shown very clearly in the tests of the 12-in. J & L Junior beam, in which the initial load first used was 400 lb. Three series of readings were taken with this initial load, but consistent readings could not be obtained, the third series showing as high negative deflections as the second series showed positive deflections. But with an increase of the initial load to 500 lb, the difficulty was much less. It may therefore be concluded that with both standard beams and J & L Junior beams the design load produces no residual deflection of engineering significance.

From among the conclusions, the following are quoted (with the original numbers):

(2) The residual deflection under repeated loads of both standard beams and J & L Junior beams is negligible within working stresses. Where a slight deflection remains after the first application of a load producing the usual working stresses, no increase in deflection will occur after a second or third application of the load.

(5) The maximum shearing unit stress which can be developed before web buckling occurs in thin-webbed beams with stiffeners at supports and at load points is between the calculated unit load which can be carried by a fixed-ended column having a height equal to the length of a 45-deg strip of the beam and a similar column having a length equal to the depth of the beam. For the more slender webs, the buckling strength of the web is represented very closely by the unit load carried by a vertical strip of the beam.

(6) For J & L Junior beams with the compression flange not restrained against sidewise buckling, and without stiffeners at either the supports or at the load points, two distinct laws govern the strength: (*a*) for slenderness ratios of less than about 150, the shearing strength governs, manifesting itself by a buckling of the web, while (*b*) for slenderness ratios greater than about 150, the fiber stress governs, manifesting itself by sidewise buckling of the compression flange.

(*a*) The shearing stress which may be developed is approximately equal to the ultimate unit load of a vertical strip of the web considered as a round-ended Euler column.

(*b*) The fiber stress which may be developed is given by a formula of the type derived by Moore in Bulletin No. 68, and for the 8-in., 10-in., and 12-in. beams it is, approximately, $S = 24{,}000 - 40\,\frac{ml}{r'}$. For the 6-in. beams the strength is greater than that given by this formula.

(8) Where the bearing block is very close to the end of the beam, the Carnegie formula, $S_b = \frac{R}{t\left(a + \frac{d}{4}\right)}$, in which S_b is the bearing unit stress in pounds per square inch, R is the end reaction in pounds, t is the thickness of the web at the middle of the height in inches, a is the distance from the end of the beam to the inner edge of the bearing block in inches, and d is the depth of the beam in inches, was found to fit the results of the tests of J & L Junior beams fairly well, and it is recommended in preference to the Hudson formula for general use with I-beams without stiffeners over supports and under load points. (Milo S. Ketchum and Jasper O. Draffin, *University of Illinois Bulletin*, vol. 29, No. 45, Feb. 2, 1932, the same publication also referred to as Bulletin No. 241 of the Engineering Experiment Station, pp. 5–41, 15 figs. and 15 tables, *ec*)

FOUNDRY (See also Fuels and Firing: The Working of Rotary Pulverized-Fuel-Fired Melting Furnaces)

Manufacture of Centrifugally Cast Brake Drums

IN A METHOD employed at the Campbell, Wyant & Cannon Foundry Company, Muskegon, Mich., the brake drum consists of a steel shell on which a cast-iron liner is fused centrifugally. This liner provides the wearing surface for the brake, while the steel shell insures the necessary stiffness and mechanical strength of the drum. The process is based on the use of a highly preheated steel drum. This drum is first cleaned by sand blasting, whereupon the drums are placed in a gas-fired furnace, and after emerging therefrom are given a coating of fluid fluxing material. The drums are next electrically heated to incandescence. To do this the drum is placed over the core on the swinging head of the induction-type heater manufactured by the Thompson-Gibbs Welding Company, Bay City, Mich. As soon as the drum is in position, the operator on the other side of the heater throws a lever that opens the air line to an air cylinder on the back of the heater. The air-actuated head of the heater closes and is held in place for the heating operation. The operator then presses a button to energize the induction coils.

The drum now is in the magnetic field of the heavily wound primary coil, where it forms a shortened secondary of only one turn. As may be expected, the induced current generated by the magnetic field and imposed on the drum, acting as a single-turn shorted secondary, is of high amperage and comparatively low voltage, with the result that the drum becomes incandescent within a short time. In the induction preheaters used at the Campbell, Wyant & Cannon plant, the drums become incandescent in approximately 7 sec.

The operator then removes the incandescent ring from the core with a fork and places the ring in the chuck of one of the centrifugal casting machines.

The centrifugal casting machines are mounted radially, 12 to a turntable, which operates continuously and makes one complete revolution every 3 min. After the hot drum is inserted in the chuck and the table has progressed one-twelfth of a revolution, another operator pulls two levers on the front of the casting machine. These close the chuck jaws and automatically lock them in position.

The closing mechanism for the jaws consists of a piston operated by oil, which under ordinary conditions exerts sufficient pressure with a margin of safety to hold the chuck jaws closed. However, as an additional safety measure, there is incorporated a mechanical locking device that will prevent release of the jaws in the event of oil-pressure-pump failure or a leak in the oil-piping system or the reservoir tank.

The pouring lip is formed by making the edge slightly lower at that point for about 4 in. At the opposite end and on the right side may be observed what appears to be an additional handle. However, it serves as a regulating flow-off spout to adjust the correct quantity of metal when it is filled from the hand shank from the furnace.

An adjustable stop under the flow-off may be raised or lowered so that any given amount of metal within certain limits may be retained in the pouring basin.

Such close control of the metal is necessitated by the narrow tolerances established upon the thickness of metal desired in the lining. Numerous tests indicate that in the average passenger-car drum a metal thickness of approximately $^1/_4$ in. allows sufficient metal for a roughing cut, a finishing cut, and a final grinding operation.

Thicker metal lining than that mentioned would make the drums heavier than necessary. Hence, checks are made on the metal-lining thickness at regular intervals by selecting lined drums at random and weighing them while still hot as they are taken out of the chucks. (Edward W. Beach and Edwin Bremer, *The Foundry*, vol. 60, no. 7, May, 1932, pp. 26–29, 5 figs., *d*) (This is the third article in a series, the first of which appeared in the March issue of *The Foundry*.)

Permanent-Mold Castings

PERMANENT-MOLD castings are made in a multiple 12-head machine and four single-head machines. The multiple-head machine is a highly complicated device and is entirely automatic in operation. Each mold is mounted vertical and is in two parts, with one half fixed and the other half movable. The entire mechanism revolves by motor operation, and by air operation and a series of toggle arms and cams each mold is opened and closed automatically. Within certain limits the machine can be adjusted to revolve at any desired speed. In this particular instance the machine has a speed of one revolution in 3 min, or 20 rphr. This means that it produces a complete casting, and in some instances two castings, from each of the 12 molds every 3 min.

Castings range in weight from 10 to 100 lb. Assuming that the average weight of each casting is 20 lb, it is apparent that the hourly production of the machine is 4800 lb of castings, or 38,400 lb for an 8-hr day. This represents ideal operating conditions, and of course rarely is realized.

The machine occupies a floor space of approximately 150 sq ft and requires the attention of three men. One man sets the cores, a second man pours the iron, and a third man directs the castings into an opening in the floor above a chute that conveys them to the lower-floor cleaning room.

Mold cavities are lined with a mixture of clay and water glass. This material is applied easily and is readily repaired when necessary. A further coating of soot is deposited on the face of each mold before it is filled with iron. An acetylene flame performs that function at a point that may be regarded as the beginning of the cycle.

In operation the molds generally attain a temperature of approximately 300 F. Experience gained over a considerable

period of time seems to indicate that consistently better results are secured at that temperature than at any temperature above or below. At a low temperature, the resulting castings are chilled and cold-shut. At a high temperature, the molten metal shows a tendency to stick to the face, the castings are rough, and the sprue opening becomes distorted and eroded.

Due to a thinner section, a faster cooling speed, or both, in the permanent-mold castings, the iron for these castings carries a higher carbon and a higher silicon content than the iron destined to be poured into the sand-mold castings. Under normal conditions the permanent-mold castings are poured in the forenoon and the sand-mold castings in the afternoon. The charges for the furnace are made up principally from steel scrap, with certain additions of ferrosilicon, ferromanganese, and petroleum coke to raise the silicon, manganese, and carbon content. (Pat Dwyer in *The Foundry*, vol. 60, no. 7, May, 1932, pp. 18–21 and 72, 9 figs., *d*)

FUELS AND FIRING

The Working of Rotary Pulverized-Fuel-Fired Melting Furnaces

THE objects of the rotary furnace are said to be, first, to eliminate the guesswork involved in operating the cupola and, second, to open up the field for uses of cast iron not restricted in quantity of any one of its elements. Cast irons have been introduced, for example, with phosphorus from 0.06 to 1 per cent and chromium from 0.5 to 18 per cent.

To melt and pour certain irons requires an extremely high temperature, and the ability to provide it is perhaps the most important feature of the rotary furnace. Temperatures in ordinary practice without delay have reached 1650 C. The furnace body consists of a steel shell lined with a rammed lining, acid or basic, and mounted on two tracks that run on oscillating rollers. The body is rotated by means of a motor gear box and chain drive, the rotating gear being so arranged that a very slow motion is used for tapping purposes. For raw materials cast-iron scrap of any shape and size that will pass the charging door down to borings can be melted without any special arrangement. Steel has been used and poured without trouble up to 100 per cent. The calculation of lining costs is based on a life of 140 heats without patching, equivalent for the size described to 700 tons of metal.

The mechanism of the process consists of introducing heat into the rotating furnace with the object of raising the refractory lining to a very high temperature, the hot products of combustion then passing forward into the flues to the chimney stack.

The intense heat in the furnace lining is transmitted during rotation directly to the metal bath by actual contact, thus overcoming the heat-insulating power of the slag, which, however, protects the metal from contamination by gases. The heat is generated by the burning of pulverized coal on a refractory lath-type grid situated in the combustion chamber, somewhat on the principle of a bunsen burner with its gauze flame carrier.

The coal is carried on and burned by means of an air supply raised to a suitable temperature in a regenerator situated in the exhaust flues, and driven forward by the blower. The coal, except for that used in the initial lighting up, is anthracitic, and can be obtained from any suitable coal measure, typical analyses of such already having been given. Since the main feature is to concentrate the absorption of heat into the bath of metal, it is necessary to control the combustion of the coal—that is, the flame—at a position predetermined in the design of the furnace. This position is immediately in front of the grid in the combustion chamber.

In the discussion which followed, Dr. P. M. McNair considered as erroneous the statement to the effect that the heat was imparted to the metal principally from the roof and walls of the furnace. Dr. McNair contended that the heating was effected solely by the flame itself. This had a temperature of 1750 deg. It passed heat to the walls of the furnace, but could never raise the temperature of the walls to that figure when the temperature of the metal was 1650 deg. (W. Scott and S. E. Dawson in a paper presented to the London and Lancashire Branches of the Institute of British Foundrymen, abstracted through *Foundry Trade Journal*, vol. 46, no. 824, June 2, 1932, pp. 335–337, 8 figs., discussion pp. 337–338, *d*) (Compare *Metallurgia*, vol. 6, no. 32, June, 1932, pp. 35–38, 9 figs.)

INTERNAL-COMBUSTION ENGINEERING

New Burmeister & Wain Double-Acting Two-Stroke Oil Engine

WHAT is said to be an outstanding engine has been invented and developed after a very careful analysis of the relative performance of various types of engines made possible by the published tests of the Marine Oil Engine Trials Committee. The largest land engine is an eight-cylinder unit rated at 18,500 bhp, with a continuous maximum output of 22,000 bhp. It is being constructed for the Copenhagen Electric Power Station and will be the largest stationary oil engine in the world. Because of lack of space only certain features are reported here.

In order to obtain a positive scavenge of the straight-through type in both the top and the bottom ends of the cylinder, a centrally placed scavenging belt is used, with exhaust piston valves at either end of the cylinders, so that as soon as the scavenge ports are uncovered by the main piston the scavenge air flows upward or downward as required and leaves the cylinder through the ported exhaust piston valves. The scavenge air is furnished by a slow-speed electrically driven or chain-driven blower, to which reference will be made later.

A diagram of the scavenge timing is reproduced in Fig. 5. Indicator cards of the main cylinder and light-spring cards for the exhaust stroke show that the card from the piston valve is a very full one, with a high mean pressure, indicating that the piston valve develops a certain amount of useful work and represents an increase in engine horsepower of about 10 per cent. Full particulars of such indicator cards were given in Dr. H. H. Blache's paper on "The Marine Oil Engine," read before the Institution of Naval Architects in March, 1931, and reprinted in an abstracted form in *The Engineer* of April 10, 1931.

The section through one of the low-pressure rotary blowers used is shown in Fig. 6. The blower differs from other rotating blowers in the particular shape of the teeth, which are so designed as to allow the air to be drawn in and discharged longitudinally through the rotors and their end surfaces, and not, as is more usual, from the teeth of the rotor. The turboblowers of this type used for the East Asiatic Company's ship are designed to run at 400 rpm and have a rotor diameter of 700 mm, or $27^9/_{16}$ in. They are, as was found during an inspection of the machinery of the *Amerika*, remarkably quiet in operation, and they may be either directly driven by electric motor or chain driven from the main crankshaft. The details of the big stationary engine referred to above are given in the illustrations in the original article, which cannot be reproduced

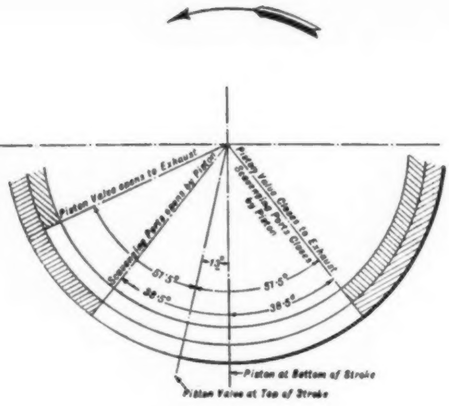


FIG. 5 SCAVENGING DIAGRAM

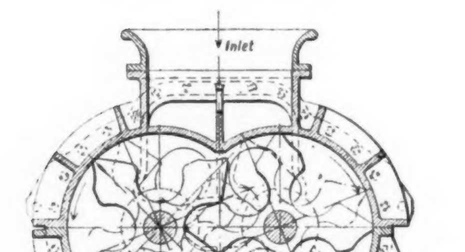


FIG. 6 SECTION THROUGH BLOWER

here. One of the features of this engine are the large sprocket wheels provided for the chain drive. (*The Engineer*, vol. 154, no. 3992, July 15, 1932, pp. 67–68, 7 figs. and a double page of plates, *d*)

Diesel Cylinder-Liner Wear

LINER wear on Diesel engines forms an important item of the maintenance bill—not on account of the rate of wear, but on account of the expense of new liners. The last annual report on Heavy Oil Engine Working Costs gave numerous figures regarding the amount of wear. Individual measurements vary widely, but the average appears to be $1^1/_2$ thousandths of an inch per 1000 hr running for four-stroke engines and $2^1/_2$ thousandths for two-stroke engines. High-speed engines show about $2^1/_2$ thousandths, and The American Society of Mechanical Engineers is said to report an average of 2.86 thousandths.

In the discussion of the report it was stated that the problem of liner wear depends on maintaining an oil film between liner and piston rings at the liner skin temperature. It is difficult to ascertain the liner skin temperature, but it is almost certainly above the flashpoint of the oil, so that lubrication breaks down where it is most needed. Instances were quoted to show that an excess of lubricating oil reduced liner wear, due possibly to the flushing action removing abrasive material. Concave piston heads were advocated on the ground that they prevented fuel oil from impinging on the liner and washing away the film of lubricant. One of the speakers said that double seal rings remain gastight even after abnormal liner wear, but they caused wear to be more rapid unless certain precautions were taken. It was necessary to use lubricating oil of a higher viscosity, to use as few seal rings as possible, and to place them low down on the piston. (Paper by Rear Adm. J. Hope Harrison before the Diesel Engine Users Association, abstracted through *The Power Engineer*, vol. 27, no. 315, June, 1932, editorial on p. 202, *p*)

High-Speed Engines of the Direct-Injection Type for Motor Cars and Airplanes

A REPORT has been made on engines of the direct-injection type shown at the 25th Salon of Industrial Vehicles in Paris, and a special issue of *Chaleur et Industrie* (Feb., 1932) was devoted to this subject.

General Details of Construction. As regards the pressure at the end of the compression stroke, it is said that this is of the order of 35 kg per sq cm (497 lb per sq in.), though the maximum pressure may be much higher. Two tendencies are observed here. The Lille Motor Company does not try to limit this maximum pressure, and resorts to the use of a cylinder open at both ends, with two opposed pistons moving therein. In this way it suppresses in a very admirable manner the pressure reaction which has a tendency to rupture the crankcase. Other constructors, on the other hand, seek to limit this pressure, and one, for example, uses a compression ratio of 13 in order to reduce the compression as much as possible. No matter what is done, however, the Diesel engine is subjected every twentieth of a second during combustion to a pressure of the order of 45 to 70 kg per sq cm (639 to 994 lb per sq in.), while in the gasoline motor it does not exceed 30 kg during a much shorter time. It is therefore necessary to make the mechanical parts of a Diesel engine very much stronger than those of a gasoline engine, and this makes the Diesel engine heavier for the same specific output. This leads to lightening and improved construction of pistons, cylinders, etc. The cylinders are of a design somewhat different from that considered good enough for slow-speed engines. The liner, made of particularly simple design, runs freely into the jacket, hollowed out for water circulation. Water-tightness is secured by means of several rubber gaskets placed in slots of hemispherical section and made partly in the liner and partly in the jacket. On the other hand, however, the Diesel engine does not use the magneto and spark plug of the gasoline engine, and saves that much in the use of such delicate and complicated apparatus.

Lubrication. As regards crankshaft lubrication in the Peugeot-Junkers engine, the oil pump has three gears. Its combination pump is permitted to inject both air and oil, producing in this way an emulsion that penetrates better than pure liquid during the very short time when the lubricating hole in the shaft is in communication with the corresponding hole in the brass. The small end of the connecting rod is equipped with anti-friction metal carefully cast and then machined in a lathe. Apart from a hollowing out to provide room for metallic particles, the internal surfaces in contact with the bearings on the crankshaft are made very smooth in order to maintain the tightness and the pressure of the oil film over the length of the bearing surface.

In general the unit pressures on crankshaft surfaces are considerably in excess of those encountered in gasoline engines, and therefore the viscosity of the lubricant, which usually decreases with the increase of pressure, must be very closely held to the desired value. As a result there is a tendency to

increase the size of the crankcase in order to augment the reserve of oil, and thus bring about a better cooling.

Roller and Block Bearings. The Nadella Company shows some roller bearings where cylindrical rollers, the diameters of which vary from 2 to 5 mm (0.078 to 0.196 in.), are entirely free to move without any kind of guides. The rollers roll with two films of oil between, and it is only when a shock or an overload is encountered that the rollers begin to turn. The Lille Motor Company uses a "block" bearing for the side heads of the connecting rods, the bearing surrounding the cylinder and working in traction. The block, which is analogous to a roller, but is not guided, has the advantage that it can resist better the lateral effort by localizing the pressure at a predetermined point. In so far as the author of the original article is aware, as he states, there are only a few machines—used in sawing—which employ connecting rods working by traction. The application of such an arrangement in an opposed-piston engine is a bold innovation.

Injectors. The design of the injector is governed by the shape and direction of the jet appropriate to a combustion chamber of the selected shape. On the other hand, however, the pump, the feed line, and the injector with its atomizer are usually made in a single unit. This makes it necessary for the designer of the motor and the manufacturer of the pumps to cooperate in the layout of their machinery. A very important factor affecting the operation of the pump-injector unit is that the injection pressure is proportional to the square of the linear velocity of the piston in the fuel pump. The injector does not atomize the fuel efficiently if sufficient pressure is not available. If this happens and if no device is provided to cover the atomizer orifices previous to injection, the fineness of the droplets of the fuel will not be sufficient to assure good combustion at low engine speeds. It is stated, however, that the Lille Company obtains an excellent atomization and considerable flexibility of operation with an open injector and very simple pumps. Brief mention is made of the air, fuel, and oil filters, as well as the starters. The article describes two German types and a British one manufactured in France, and in some detail the Renault type. In this case, high compressions were adopted in order to reduce the fuel consumption and to avoid thermal fatigue of the engine parts. With the high compression goes rapid ignition and a combustion which ends 25 deg before the upper dead center of the piston. A few words are devoted to the Panhard valveless motor. In this motor the use of linings prevents the wearing of the cylinder out of shape and leakage at high pressures Central injection is used, which results in the production of a combustion chamber of rational shape, due to the fact that the upper part of the piston is hemispherical. (J. H. Coblyn and A. Mandel in *Chaleur et Industrie*, vol. 13, no. 143, March, 1932, pp. 243–246, *d*)

MACHINE PARTS

Making Helical-Gear Segments Serve as Cams

ONE of the figures of this article shows a shaft *A* (Fig. 7) having an intermittent rocking movement which is alternately clockwise and counterclockwise. The range of these movements is through an angle of about 5 deg. This rocking lever is required to impart an endwise movement to the square bar or shaft *B*. For this purpose a segment of a single helical gear *C* is attached to lever *D*, and the helical pinion *F* of equal angle, but of opposite hand, is fitted to the shaft *B*. Shaft *B*, being square, cannot rotate, and is therefore forced to move endwise.

The helical segments and the helical pinions used in this construction were much less expensive than cams. A complete ring gear furnishes enough segments for several machines. By making the number of teeth in the pinion a multiple of four and cutting four keyways in the shaft hole, it is possible to bring new teeth of the pinion into the working position when wear takes place by changing the position of the gear on the shaft. When the square shaft *B* can be made to serve equally well in any position, only one keyway is necessary, as the shaft and gear can be keyed together as a solid unit and relocated in one of four positions to bring unworn teeth

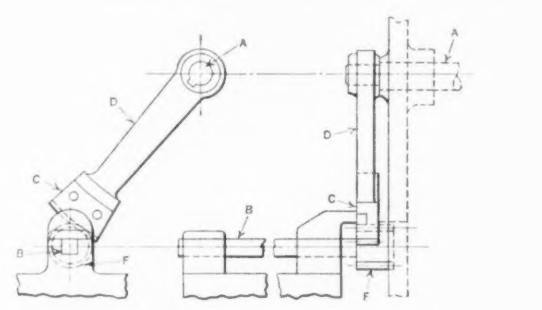


FIG. 7 HELICAL-GEAR SEGMENT AND PINION USED AS CAMS TO PRODUCE LONGITUDINAL RECIPROCATION FROM ROCKING MOVEMENT

into contact with the segment *C*. The segment *C* is supported on each side, a roller support being used when necessary to reduce the friction load. Gears with teeth having a helix angle of 45 deg or more give satisfactory performance in this kind of service. (H. W. Kitchen in *Machinery* (New York), vol. 38, no. 9, May, 1932, p. 661, *d*)

MACHINE SHOP

Determining the Value of Tungsten Carbide Milling Cutters

THIS article on tungsten carbide milling cutters is based on recent tests conducted at the Brown & Sharpe Manufacturing Company's plant, Providence, R. I. An equation was formulated which, when solved for values obtained in high-speed-steel tests, indicated what performance would warrant the use of tungsten carbide.

The first term of the first equation represents the cost of the cutter per piece machined. It will be noticed that the actual number of grinds in the life of the cutter is expressed by the term $(N_g + 1)$. This is based on the assumption that the cutter has been ground before being placed in stock, and, accordingly, the expense of one grinding will be included in the initial cost. The second term of the equation represents the cost of grinding the cutter per piece machined. The third term represents the cost of changing the cutter for grinding, while the last term includes the cost of machining the piece at the regular rate charged in milling-machine practice.

It is worthy of mention that the results obtained in some of the tests using high-speed-steel cutters exceeded the performance that would ordinarily be expected in common machine-shop practice. This fact suggests that if the same attention that is now given to the newer cutting alloys were given to high-speed steel, the performance of the latter would be much more efficient.

Tests indicated the importance of using more teeth on a cutter. In one test the number of teeth on a 6-in.-diameter

cutter was increased from six to twelve, and the feed was raised so as to keep the chip per tooth less than 0.013 in. The increase in the number of teeth increased the power consumption by about 70 per cent, but raised the production to 21,020 in. in 1036 min—nearly double that obtained with the six-tooth cutters. This test also indicates that the probable speed to be used with tungsten-carbide-tipped cutters milling cast iron is approximately 200 to 235 ft per min. (B. P. Graves, Director of Design, Brown & Sharpe Manufacturing Company, Providence, R. I., in *Machinery* (New York), vol. 38, no. 9, May, 1932, pp. 650–653, illustrated, *ep*)

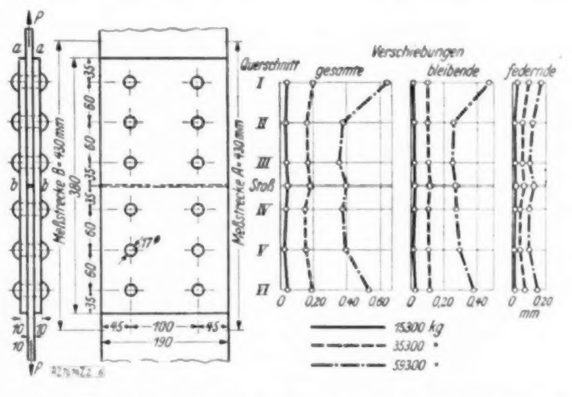
MECHANICS (See also Engineering Materials: Strength of Light I-Beams)

Tests on Riveted Joints Subject to Frequent Changes of Loading

TESTS were carried out in order to determine the desirability of using steels of high strength in riveted joints subjected to frequent changes of load as compared with the use of the ordinary structural steel. In this case the comparison is primarily between the German ST37 and ST52 steels, although several other steels were used in the tests. The specifications for these steels are given in the original article. Another purpose of the test was to determine whether the present methods of calculation of stresses on riveted joints are satisfactory where the joint is subject to strongly varying loads. This was considered to be important, as the present views on the strength of riveted joints have been derived largely from tests in which the loads were increased gradually or step by step, and where the changes of loads were not very frequent. All the tests were performed on flat stock with the rolling skin on, and where holes were drilled, this was done with the standard good grade of workmanship. The original article gives the stress under extended periods for alternating tensile stressing where approximately 2,000,000 alternations of load have been applied. The average original strength was 18 kg per sq mm in the case of steel 37 and 20 kg per sq mm in the case of steel 52. The ratio of the original strength D_{su} to the total tensile strength K_z was on an average 0.47 in the case of steel 37 and 0.34 for steel 52. This would indicate that steel 52 has on an average 10 per cent higher original strength than steel 37, and that the ratio of D_{su} to K_z is higher in the case of steel 37 than of steel 52. It was found that the lowest values of D_{su} in steel 52 occur in the case of bars where the surface shows fine notches. It has been found in general that the character of the rolled surface is of considerable importance, which is illustrated in the original article by a reference to a steel the composition of which, however, is not given.

The recent experiments of Wellinger (thesis 1931, Stuttgart) have shown how one must proceed with modern structural steels in order to obtain in the rivet as high a rupture strength as possible. These strengths can very nearly attain the elastic limit of the material with suitable steel for the rivets with proper length of shank, with suitable heat treatment, proper selection of riveting pressure or weight of hammer, and proper pressure of the air. The squeezing forces on the rivets produce friction in the rivet joint, which means resistance to slipping, and it is only after this resistance to slipping has been overcome that the rivets come to touch the walls of the rivet hole, and it is only then that the rivets begin to carry the direct load. With well-made rivet joints of steel 37 and rivets of steel 34 and with satisfactory distribution of the rivets ($\sigma : \sigma_l : \tau = 1 : 1.45 : 0.5$, where σ is the stress in the belt, σ_l the pressure on the wall of the rivet hole, and τ the shearing stress on the rivet), the resistance to friction so affects the ability to carry the load that with permissible loads the maximum stress occurs not at the first rivet hole but in the solid plate beyond that hole. This has been shown in a rivet joint which has carried 1,786,400 alternating stresses from 0.5 to 22.7 kg per sq mm, as shown in Fig. 1 of the original article. It is therefore proper in designing and manufacturing riveted joints to strive to obtain the highest possible resistance to sliding.

One of the most interesting parts of the article deals with observations on sliding in riveted joints. When one considers changes in shape of a riveted joint from Figs. 8 and 9, one notices first of all the displacements at *aa* and *bb* (Fig. 8), because of the great difference in stresses which occur here



FIGS. 8 TO 12 MAGNITUDE AND DISTRIBUTION OF DISPLACEMENTS IN A RIVETED JOINT MADE OF STEEL NO. 52 AT THREE DIFFERENT LOADINGS

The loads have been increased in steps. The rivets used are in the state in which they were delivered with a Brinell hardness of H_n = 214 kg per sq mm

P =	15,300 kg	35,300 kg	59,300 kg	
σ =	9.7 kg per sq mm	22.5 kg per sq mm	37.8 kg per sq mm	$\sigma : \sigma_1 : \tau$ =
σ_l =	14.9 kg per sq mm	34.3 kg per sq mm	57.6 kg per sq mm	1 : 1.52 :
τ =	5.6 kg per sq mm	13.0 kg per sq mm	21.8 kg per sq mm	0.58

and differences in elongation of the plate and strap. At *aa* the center plate has to carry an external force P, while the straps contribute their share of carrying primarily through resistance to slipping. At *bb* the straps alone carry the externally applied force P. The magnitude and distribution of displacements are shown in Figs. 10 to 12, applying to a joint such as shown in Figs. 8 and 9. The numerical values given in the caption have been obtained by increasing the load by steps. Obviously the greatest motion is observed in the cross-sections I and VI and also under shock. From Figs. 10 to 12 it would appear that the displacements run up to quite substantial values even with low loads. This in part is due to the circumstance that sliding resistance reduces the back spring and that in making riveted joints primary stresses are induced which are more or less released in loading and unloading a joint in service. As regards the behavior of riveted joints of the same dimensions but with different squeezing forces, a figure in the original article shows the behavior of the rivets in three types of riveted joints. It has been found that with frequently repeated loads the changes of shape are greater than in plain tensile tests. Two figures in the original article show just what happens with the riveted joints shown in Figs. 8 and 9. The permanent and total changes of shape increase, while the elastic movements are but little affected.

In the generation of permanent changes the matter of friction

is of great importance, as shown by curves in the original article. The remainder of the article deals with changes in the rivets and destruction of rivets by the application of frequently repeating loadings. Another part of the article deals with the coefficient of strength of steels in riveted joints. This cannot be abstracted here. (Otto Graf, Professor at the Technical High School, Stuttgart, in *Zeitschrift des Vereines Deutscher Ingenieure*, vol. 76, no. 18, Apr. 30, 1932, pp. 438–442, 24 figs., *e*)

POWER-PLANT ENGINEERING

Series Operation of Boilers Intended for the Utilization of Energy of Hot Water

JEAN REY in a paper presented at the tenth anniversary of the journal *Chaleur et Industrie*, showed that if it is desired to utilize the heat energy of a boiler fed with hot water, the temperature of the boiler must not be selected haphazardly. There exists a certain definite value of temperature corresponding to the maximum useful effect, so that if the boiler operates between the limits of temperature T_0 and T_2, the optimum boiling temperature T_1 is characterized by the fact that the weight of steam produced at that temperature multiplied by the available fall per unit of weight between the temperatures T_1 and T_2 gives a greater quantity of heat than the one that can be obtained at any other temperature of boiling between the limits T_0 and T_2. On one hand it is known that the weight of steam of absolute temperature T_1 that can be produced from 1 kg of water at the temperature T_0 is given by the equation $(T_0 - T_1)/r_1$

On the other hand, Rateau gives the following expression for the heat drop made available by the adiabatic expansion of 1 kg of dry saturated steam from temperature T_1 to T_2:

$$(T_1 - T_2)\left(\frac{r_1}{T_1} + \frac{T_1 - T_2}{T_1 + T_2}\right)$$

Rey demonstrates that, within the limits of temperature which are of particular interest, the optimum boiling temperature T_1 may be expressed in terms of T_0 and T_2 by the following equation:

$$\frac{T_1 - T_2}{T_0 - T_2} = \mu$$

where μ is 0.4871. Rey gives expressions for the maximum work that can be produced by 1 kg of water at the temperature T_0 without passing through the value of the optimum boiling temperature T_1, and also gives an expression for the heat of vaporization r, by means of which he calculates the constants.

From the foregoing it would appear that the optimum boiling temperature lies in the neighborhood of the arithmetical mean of the two extreme temperatures. It would appear, therefore, that when the operation of a boiler is so regulated as to produce the maximum useful effect, the water that has not been evaporated at that temperature coming from the boiler can well be used as a source of heat of which the deviation of temperature from that of the cold source is of the order of one-half of the original spread of temperature, i.e., $T_0 - T_2$. On the other hand, the weight of steam produced from 1 kg of water at the optimum temperature T_1 is always very small, so that the weight of water coming from the temperature T_1 is only little different from the original weight entering into the boiler at the temperature T_0. From the foregoing it would appear that, under certain conditions, utilization of the energy of hot water in several boilers connected in series may become of real interest.

Before proceeding to the calculations to determine various ways of utilizing hot water in several boilers in series, the author examines the effect of series operation on the heat motor, in this case a low-pressure steam turbine. Obviously, notwithstanding the fact that several boilers are used in series, it is not at all necessary to have a separate turbine for each of the boilers. It is much simpler to combine all of the separate turbines into a single multi-vapor turbine or a mixed turbine equipped with as many admission valves as there are boilers.

Comparing such a mixed turbine with an ordinary turbine fed from a single boiler, it will be immediately noticed that the passage of hot water through several boilers increases the weight of steam working in the last stage of the turbine, which calls for a material increase in the diameter of that stage, and this results in a reduction of the rpm of the turbine. Moreover, the necessity of building the turbine with at least as many cells as there are boilers may lead to the use of a number of cells greater than that which would have been sufficient in the case of a single boiler. Hence, the heat drop in each of these cells, and particularly in the last one, may become too small, thus increasing the velocity of the steam in the last stage. All other conditions being the same, this velocity of the steam makes it necessary to increase still more the diameter of the last stage, which consequently reduces still more the velocity of rotation.

Finally, in order to maintain the proper efficiency this diminution of the velocity of steam causes a nearly proportional decrease in the peripheral velocity of the rotors, and as their diameters are determined by the volume of steam that goes through them, a third reason becomes available for reducing the rpm of the turbine. A turbine fed with several kinds of steam at low pressure will therefore always have a low velocity of rotation, and can therefore be coupled directly to the alternator that it drives. The author adds that while the theory underlying all of these considerations is unquestionably correct, its importance proved to be much smaller than might have been expected when it came to the actual installation of a turbine using several kinds of steam. As a matter of fact, an increase in the number of boilers is of value only up to a certain limit, which is fairly rapidly reached. Hence, the design of the last stage of a turbine taking care of several boilers will be but little different from that of the last stage of a turbine fed from a single boiler. Even in the latter case it is better, where possible, to use direct coupling of the alternator rather than gear drives.

The author first investigates mathematically the case of several boilers so operated as to secure the maximum individual efficiency for each of the boilers. Next he considers the case where the maximum efficiency of the entire unit is secured. He gives general formulas for the expression of the motive power, among other things, as a function of the number of boilers and the efficiency. This part is not suitable for abstracting. (P. Chambadal in *Chaleur et Industrie*, vol. 13, no. 144, April, 1932, pp. 301–308, 2 figs., *mp*)

Lancashire-Type Double-Boiler Installation

IN 1929 a Swiss concern found it necessary to increase its boiler plant consisting of three Cornish boilers of 500, 1000, and 500 sq ft heating surface and two Lancashire boilers, each of 1130 sq ft heating surface, working at 170 lb per sq in. Because of lack of space the only way of increasing the size of the plant was by removing some of the old boilers and

installing larger ones in their place. The two Lancashire boilers and the larger Cornish boiler were comparatively new, and consequently it was decided to install larger boilers in the place occupied by the two small Cornish boilers. Installation of a water-tube boiler was not considered, since there would be no standby for this boiler and also because the fluctuating demand for steam made it necessary to have boilers with large water spaces. It was therefore decided to install two double Lancashire boilers, each with about 2700 sq ft of heating surface. The new boiler, Fig. 13, consisted of a lower boiler $8^1/_4$ ft in diameter and 32 ft long, with two tubes 40 to 44 in. in diameter, and an upper boiler $7^1/_4$ ft in diameter and about $29^1/_4$ ft long, with two flue tubes 34 to 38 in. in diameter. In order to increase the effective heating surface, 50 cylindrical circulating tubes 5 $^1/_4$ to 6 in. in diameter and with a total heating surface of 550 sq ft are fitted in the flue tubes by autogenous welding. The quantity of water in such a double boiler amounts to 11,000 gal, while in a water-tube boiler capable of raising an equal quantity of steam there would be only 2200 gal. Each of these boilers weighs about 49 tons.

Retaining the three old boilers, two with 1130 and one with 1000 sq ft heating surface, and installing the two double Lancashire boilers, increased the total boiler heating surface to 8650 sq ft—i.e., by more than 100 per cent. The quantity of steam raised has been increased by 70 to 75 per cent. The two new boilers are equipped with underfeed stokers; each has also a 580-sq ft superheater and a 1940-sq ft ribbed-tube economizer.

The enlargement of the plant made it necessary to increase the height of the original chimney. Tests of the new installation are reported in detail in the original article. An efficiency of 90 to 91 per cent overall was obtained. (*The Power Engineer*, vol. 27, no. 313, April, 1932, pp. 129–131, 1 fig., *dp*)

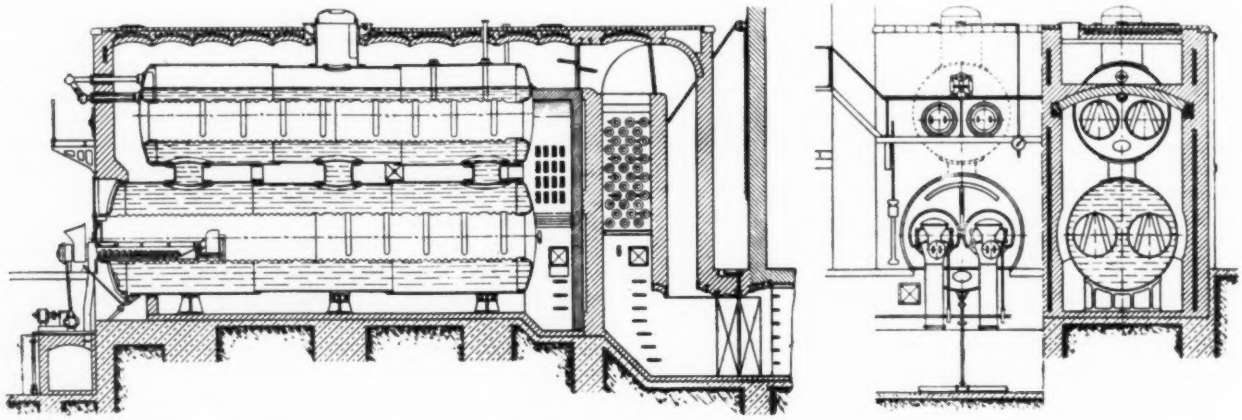


FIG. 13 SECTION AND END ELEVATIONS OF SULZER-LANCASHIRE-TYPE DOUBLE BOILERS AS DESIGNED IN ORDER TO ECONOMIZE FLOOR SPACE

Allocating Costs in Power and Process Plants

IT IS IMPORTANT to allocate costs correctly for two reasons: In the first place, it is desired to compare the cost per unit generated with the price from a public supply; secondly, the growth in the practice of departmental costing makes it necessary to compute the cost of both power and process heat to each department, or even to each important piece of apparatus. When estimating the performance of an existing plant, correct allocation is important; when contemplating a new plant it is vital.

The basic principle of fuel-cost allocation, the article states, is that the cost should be distributed between power and process in the ratio of the heat supplied to each. It is an error to distribute costs in the ratio of the steam quantities supplied without regard to heat content.

The fallacy is exposed by carrying the argument to its logical conclusion, i.e., in the case of a back-pressure machine. In this case the steam consumption of the turbine or engine is nothing; therefore, according to this argument, the power cost is nothing. This is fundamentally incorrect, because the back-pressure set abstracts some of the heat from the steam and should be charged for it. With pass-out condensing sets, the error may be slight or serious according to the conditions obtaining.

The general method of finding the correct cost allocation is to set out the steam quantities at the turbine stop valve and at each pass-out, to determine the total heat per pound of steam at each of these points, and to multiply each steam quantity by the appropriate total heat. This gives the total heat supplied to the turbine and the total heat delivered to each pass-out, whence the total heat supplied to power can be obtained by subtraction. The ratio of each of these latter quantities to the total heat supplied to the turbine is then the proportion of the total fuel cost that each should bear. It is possible to calculate the heat supplied to power directly, but it becomes tedious when the set is condensing and especially when it has two pass-outs; to obtain this quantity by subtraction is simpler.

Steam quantities are a matter of estimation with projected plants and metering with existing plants. Total heats can be found either by steam tables or by a Mollier diagram. The author prefers the latter method.

When using steam tables one should remember, first, that the total heats given refer to dry saturated steam and the pressures quoted are usually absolute. The author shows how to derive the total heats from the Mollier diagram and gives an actual example of the distribution of costs. (*The Power Engineer*, vol. 27, no. 315, June, 1932, pp. 205–208, 2 figs., *p*)

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer.

SYNOPSES OF A.S.M.E. PAPERS

THE papers abstracted on this and following page appear in the current issues of the Applied Mechanics, Hydraulics, and Machine-Shop Practice sections of A.S.M.E. Transactions, or are available on request in mimeographed form. These sections have been sent to all who registered in the similarly named Divisions. Other sections are in the course of preparation and will be announced, when completed, in later issues of "Mechanical Engineering." Copies of the Transactions papers may be obtained by those not registered in these Divisions by addressing the Secretary of the A.S.M.E., 29 West 39th Street, New York, N. Y.

APPLIED MECHANICS

Flow of Steels at Elevated Temperatures

FLOW tests of steels at elevated temperatures, as carried on in the Research Laboratory of the General Electric Company, are described in this paper. The object of these tests is to predict the ability of materials to maintain dimensions under stress at operating temperatures for long periods of time. Various methods of testing are used. Some are for the purpose of obtaining a mass of information in the shortest possible time; here the rate of flow is measured for a series of successively reduced stresses at each of several successively increased temperatures. Others are designed to furnish more fundamental information regarding the nature of flow; here new specimens are subjected to constant stress at a uniform temperature for long periods of time. Still another one is the constant-extension test where the stress is varied with time to maintain a constant total elongation (elastic plus plastic). (Paper No. APM-54-6, by F. P. Coffin and T. H. Swisher.)

The Flexibility of Corrugated Pipes Under Longitudinal Forces and Bending

PIPES with circumferential corrugations are being used in expansion bends in steam lines and in other applications where the maximum longitudinal or bending flexibility is required. In the present paper the longitudinal flexibility is calculated for several types of corrugations, and from this a "reduced modulus of elasticity" is derived by which corrugated pipes can be calculated as if they were smooth. It is then proposed to use this same reduced modulus for calculating the bending of corrugated pipes. A set of experiments in which a piece of corrugated culvert pipe was tested in direct compression and in bending, is described which check these results. (Paper No. APM-54-7, by L. H. Donnell.)

Celluloid as a Medium for Photoelastic Investigation

THIS paper deals with the physical properties of celluloid and their bearing on its use in the photoelastic method of stress determination. The authors present curves and test data on American-made celluloid, showing stress-strain and time-creep relations. Their results indicate that the physical constants for this material are not fixed, but have a consistent variation with speed of loading. Their work shows that celluloid is not perfectly elastic under any condition of loading. They point out some important peculiarities in the interrelation between photoelastic color and stress and strain. (Paper No. APM-54-8, by R. H. G. Edmonds and B. T. McMinn.)

Kinematography in Photoelasticity

PHOTOELASTICITY is one of several methods available for stress analysis. Kinematography in photoelasticity was made practicable by the introduction of the monochromatic method and should be found useful in the study of gear action, tool cutting, impact stresses, and in the phenomenon of failure.

Moving pictures of 15 models in 29 set-ups are presented which show a variety of stress-distribution patterns and their formations. Stress concentration can spring from various sources such as holes, grooves, notches, sharp curves, scratches, and the edges of flat steel dies.

A layer of rubber, lead, or wood has been found to eliminate stress concentration due to a die. Stress concentrations have been found to be mutually destructive when their sources are many and close. Application of this principle is made to the design of a thread, and results from direct tests are shown which substantiate it.

Moving pictures are presented showing the stress fluctuation during impact, and from these the increase of stress in pure bending and the time of stress oscillation are determined, the latter being in good agreement with theory. (Paper No. APM-54-9, by Max M. Frocht.)

Photoelastic Study of Shearing Stresses in Keys and Keyways

THE technique of photoelastic determination of stresses in structural members, using bakelite as the transparent medium, is described. The mechanical properties of this material and the process of annealing it for the removal of the internal stresses are given. The shearing stresses in keys and keyways are investigated. It is shown that it is desirable to round the corners of the keyway, with a corresponding chamfering of the key. The use of the color fringes called "isochromatics" for the determination of shearing stresses has been found very helpful and is highly recommended by the authors. (Paper No. APM-54-10, by A. G. Solakian and G. B. Karelitz.)

The Center of Torsion for Angle and Channel Sections

THE author presents a method of determining the position of the center of torsion in a channel section when the bar, held at one end, is subjected to a torsional couple. The case of the angle section is first investigated and an expression for the distance from the center line of leg to the center of torsion is determined. The case of the channel section is then analyzed by the same method. (Paper No. APM-54-11, by W. L. Schwalbe.)

A New Type of Dynamic Balancing Machine

IN THIS paper is described a novel type of dynamic-balancing machine developed for production balancing. The machine employs an automatic compensating device, making it possible for an unskilled operator to obtain accurate readings of amount and position of unbalance correction with great rapidity. The theory underlying the action of the machine is given, and the characteristics of the automatic balancing head are investigated. The method of operating the machine is explained, and data on the accuracy of balance obtainable are included. (Paper No. APM-54-12, by Ernest L. Thearle.)

The Propeller-Type Fan

IN THIS paper a method is given showing how it is possible to present the complete characteristics of fans in a very concise manner. This is usually done by giving pressure-volume curves for different sizes and speeds. Here this relationship for all sizes and speeds is shown by three curves.

Theory is developed according to which all data for designing a fan can be determined if the volume per minute and the pressure rise, i.e., the power output of the fan, are given. In addition, it is shown how the efficiency due to air friction can be calculated, and in what way the loss due to the rotational velocity of the air behind the fan is determined by the pressure increase produced by the fan.

The limitation of the theory is then dealt with, and various restrictions regarding the validity of the assumptions made are discussed. Finally a short description of a test equipment for fans is given. (Paper No. APM-54-13, by O. G. Tietjens.)

HYDRAULICS

Time Rates of Servomotors

THIS paper supplements a previous one, "Mechanics of Hydraulic-Turbine Pressure Regulation" (HYD-52-4), which the author presented at the A.S.M.E. annual meeting in 1929. It is shown that the ratio of servomotor diameter to control-valve diameter affects the rate of motion of the servomotor much more sensitively than does the operating pressure. The smaller a servomotor, the more rapidly it approaches the condition when no movement can be obtained. On the other hand, too large a servomotor does not materially quicken the movement. Formulas are given for calculating the most economical diameters of both servomotor and control valve for a fixed working pressure. The paper is on file at the Engineering Societies Library, 29 West 39th Street, New York, where it may be consulted by those interested. (Paper by Arnold Pfau.)

MACHINE-SHOP PRACTICE

Improved Device for Recording Instantaneous Tool Pressures in Machinability Studies

THE device described permits the measurement of the three tool-pressure components during the machining of short test pieces. The advantages of the device as compared to similar devices used in the past are outlined. It is shown that the use of the piezoelectric pressure-measuring method makes possible a rigid tool mounting and the recording of relatively sudden pressure changes. The mechanical and electrical limitations are discussed, and improvements are suggested. A discussion of some of the test results illustrates the value of the device for machinability studies. (Paper No. MSP-54-6, by O. F. Gechter and H. R. Laird.)

Small Tools and Gaging for Interchangeable Manufacture

TO SECURE interchangeable parts in continuous production, proper gaging is necessary. The author describes the specifications by which the design of the correct gage can be greatly simplified. The methods by which the manufacture of reamers, taps, threading dies, drills, etc., can be held to uniformity, within proper tolerances, are covered in the paper. (Paper No. MSP-54-5a, by E. J. Bryant.)

Conventional Gages and Their Application to Duplicate Production

THE attainment of greater accuracy in present-day machines has necessitated improved gaging facilities. This article briefly treats of some important considerations in the design of gages, a description of a few special applications, and the need for standardization in gaging methods relative to machine-shop practice. (Paper No. MSP-54-5b, by Thomas F. MacLaren.)

Belt Drives With Cast-Iron Pulleys and Paper Pulleys

THIS paper gives data on the transmission efficiency of various types of belts on cast-iron and paper pulleys, and goes thoroughly into the transmissive power of oak-tanned and rubber belts on such pulleys with varying contact angle, a subject of importance in view of the prevalence of short-center drives with large transmission ratio. It is found that commonly used formulas for the effect of contact angle on transmissive power are not dependable for all combinations of belts and pulleys. (Paper No. MSP-54-7, by C. A. Norman and G. N. Moffat.)

Correlation of Casting Design and Foundry Practice

CORRELATION of design and foundry is a necessary part of any sound engineering program. However, it is quite often neglected, adversely affecting the ratio of the result per dollar. In considering the foundry the fact that individual foundry practices vary must be borne in mind. Castings are virtually assembled in the liquid state within the mold, and this principle must be borne in mind, but not overdone. Open-mindedness on the part of the designer is essential. Foundrymen must be urged to express new foundry ideas, since in new designs provision might be made to permit the use of new foundry development. Machine-made green-sand coring is a new practice being successfully used. The true bulk of a design is in the flask, not in the individual casting. Wall thickness is a general target on weight reduction. This is bad practice. Weight must be eliminated by design. The designer can help in obtaining clean castings by providing ample space for cores. Driers are a necessary evil, and the design should eliminate them wherever possible. Elimination of fins still requires development on the part of the foundry. A large proportion of foundry and engine-operation difficulties can be traced to improper determination of engine length quite often by a non-technical executive. Impatience on the part of engineers to see their designs in operation results in insufficient time for the foundry to gain necessary experience with experimental castings. Cost items accrued during productive periods should be investigated and eliminated from any new design. Elimination of foundry difficulties also means elimination of trouble to the ultimate owner. Therefore the foundryman and engineer are equally interested in the final result. (Paper No. MSP-54-8, by Alex Taub.)

Correspondence

CONTRIBUTIONS to the Correspondence Department of "Mechanical Engineering" are solicited. Contributions particularly welcomed at all times are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

Will the Boot Straps Stand the Strain?

To the Editor:

In your August issue, under the title "The Transportation Dilemma," Leon Cammen suggests a scheme for bringing about the coordination of rail, motor-truck, and bus transportation which, to one familiar with the course of development and the current problems of the transportation industries, is amazing, to say the least.

Mr. Cammen's thesis is that boom periods have been based on developments in one or two key industries, that emergence from the present depression would be accelerated by a new key industry, and that for that industry he has selected "an integrated and properly organized industry of transportation." The railroads, he says, are economically weak because of motor-vehicle competition; motor vehicles cannot operate most effectively because of limitations of the highways; the highways cannot be properly improved because the billions of dollars necessary to do the job right are not available and cannot be invested unless the enterprise promises to become self-supporting. To meet these conditions and provide the key to a return of prosperity, Mr. Cammen proposes that the railways spend an estimated ten or twelve billion dollars—an amount nearly half as large as the present total investment in steam railways. With it he will superimpose over "the entire length of our major railway systems east of the Mississippi river" an elevated highway and suspended railway, the former for high-speed motor-vehicle movement, and the latter for high-speed passenger service, leaving the surface tracks to handle the freight and local passenger traffic. The railways will collect tolls for the use of the highway.

I do not propose to question the technical practicability of the construction and operation of Mr. Cammen's "integrated" system of transportation. Indeed, one is almost safe in saying that nothing is any longer impossible, technically. The question in the case of such proposals has ceased to be "Can it be done?" and has become "Will it pay?" In considering the latter question, it is necessary to point out some of the basic facts underlying the present transportation system which Mr. Cammen has either overlooked or too summarily dismissed.

The railroads as a whole are economically weak at the present time because of the unprecedented decline in traffic and earnings which has been going on steadily since the beginning of the depression. In this the railroads are not alone. Many other industries are also suffering from declines in business volume and earnings. The railroad situation, however, is unique in that during the prosperous years when other industries were able to build up surpluses, the earnings of the railways were limited by regulation to a point which never reached the five and three-quarters per cent established as a fair return by the Interstate Commerce Commission under the Transportation Act of 1920, a return which, in itself, was not large enough to permit the upbuilding of surpluses to tide them over a depression.

Highway competition has contributed to the reduction in traffic and earnings and has become particularly severe during the depression. The railroads are handicapped in meeting this competition because their rates must produce the revenue necessary to support and maintain their investment in roadway and track, in addition to their investment in equipment, and to pay taxes on them as well. The commercial users of the highways are enjoying the use of a public facility without investment and with utterly inadequate charges for the privilege, considering the use they make of it and the inconvenience they cause the public when it tries to use the highways for other than commercial purposes.

While Mr. Cammen is silent on the point, he must anticipate a tremendous growth in the demand for transportation to make self-supporting so enormous an investment in additional facilities. There is nothing in the present situation to indicate the probability of any large or rapid increase in this demand. In the first place, the rate of increase in population in the United States is markedly declining, and some students of the problem anticipate a stationary population by 1960. In the meantime, revenue ton-miles per capita, which were growing rapidly until 1920, showed a remarkable degree of stability during the years following 1920 until reduced by the effect of the depression in 1930 and 1931. While this is subject to correction for the revenue ton-miles transferred from the railways to competing agencies during the decade, this transfer was not large enough until the beginning of the depression to invalidate the conclusion that the volume of revenue freight transportation per capita is rapidly approaching stability.

The volume of passenger traffic handled by the steam railroads has shown a tremendous decline since 1920. In that year the Class I railroads handled 47 billion passenger-miles. In 1929 this volume had been reduced to 31 billion passenger-miles. Undoubtedly, the largest part of this decline is attributable to the growth in the use of private automobiles during this period. A smaller part, amounting to approximately 6.8 billion passenger-miles, may be charged to intercity buses operating in revenue service—18 per cent of the combined railway and revenue highway travel in 1929. This combined amount, however, is 20 per cent less than the volume handled by the railroads alone in 1920, and does not offer an optimistic basis on which to estimate a large increase in revenue passenger traffic.

The conclusion is obvious, therefore, that so far as one can predict from the facts established during the past decade of boom times, the 1929 volume, or an amount very slowly increasing above it, will have to carry the burden of an additional 10 or 12 billion dollars' investment. According to Mr. Cammen's scheme, this will have to be divided between passenger traffic handled by the railways and the passenger and freight traffic which can be induced to leave the public highways and pay a toll for the use of railroad-owned highways. The experience of the railroads in recent years indicates that a return of the lost passenger traffic to the rails cannot be effected in any appreciable degree by improvements in the service, either in luxury or speed. Price is the factor controlling the revenue traffic lost to the buses by the railroads. Since the margin between the railway passenger revenue and the cost of passenger service is already approaching the vanishing point, the burden of supporting the new investment must fall almost wholly upon the highway traffic.

Estimates of the volume of freight traffic on the highways vary from 3 to 10 per cent of the combined railway and highway ton-mile volume. Assuming the top figures, the amount may

be placed at about 65 billion net ton-miles in 1929. To give the proposal the benefit of every doubt, let us assume that each highway passenger-mile produces revenue equal to the passenger-mile average of the railways, and each ton-mile produces an average revenue equal to twice the average received by the railroads. The result is a gross revenue of 1.6 billion dollars. If we assume that all the commercial highway traffic in the entire United States were to be transferred from the public highways to the railway-owned toll roads east of the Mississippi and allow 10 per cent for carrying charges on the new investment, about two-thirds of the entire revenue will be required to meet fixed charges alone. It is inconceivable that two-thirds of the highway traffic of the territory included in Mr. Cammen's plan alone would be transferred to these toll roads, and certainly it would be far less than two-thirds of the traffic of the United States. On the basis of the present outlook, the total revenues from the business handled would therefore be quite inadequate to meet the fixed charges on the investment.

But why should any commercial operator add to his operating expense a toll for operating on a railroad-owned superhighway when he has already available the public highway, of the cost and maintenance of which he has to pay but a small part and which, in most states, he would have to pay whether he used it or not?

The fact that 86 per cent of the factory-sold automobiles sell for less than $750 wholesale and that 85 per cent of the new cars are purchased by persons whose annual income is under $4500, promises little support for the superhighway in the form of tolls from the operation of passenger automobiles.

Restated, Mr. Cammen's thesis amounts to this:

The railroads have become economically weak and lack capital for necessary improvements because of competition by motor vehicles. The latter cannot operate most effectively because of limitations of the highways. Therefore, let a selected list of railroads raise new capital equal to half the present investment in all the railroads to remove the limitations on their competitors and then induce their competitors to pay them for the privilege of leaving the public highways, which are provided largely at the expense of non-commercial motor-vehicle operators and the general taxpayers (including the railways themselves, incidentally). Thus are the railroads to spend the country back into prosperity.

Having done all this, what becomes of the necessary improvements which admittedly the railroads need to make in rail-transportation facilities—which will improve the service and reduce its cost? Or shall they gradually abandon the tracks and leave Mr. Cammen's scheme without its foundation?

Mr. Cammen is right in at least one respect. There is a real job of coordination to be done in the transportation field. But it is not primarily a technical job; it is a job of developing a sound public policy—a policy which recognizes that subsidizing unregulated competitors on the one hand (Mr. Cammen has given no consideration to government-subsidized inland-waterway competition) and hampering the efforts of the railways to adapt their service and rates to the new competition on the other, is not the way to preserve and build up an admittedly essential service. That job once accomplished, the necessary technical changes in railway and road transportation will be made in character and amount according to the need and the ability of the service to support the cost, as the traffic adjusts itself to the conditions established by the policy.

C. B. PECK.[1]

New York, N. Y.

[1] Managing Editor, *Railway Mechanical Engineer*. Assoc-Mem. A.S.M.E.

TO THE EDITOR:

Without replying specifically to Mr. Peck's criticisms of the economic and financial aspects of the plan suggested in my article, "The Transportation Dilemma," may I quote from the article, the sixth paragraph, which directs attention to its purpose.

"The most important task today in so far as national economics is concerned is to coordinate the various transportation factors in such a manner as to change the present chaos into a balanced industry of transportation. It is the purpose of this article to suggest a means by which this can be done, and which will at the same time provide an enormous amount of business for our key industries and also improve the financial standing of railroad securities."

The point of view that Mr. Peck has expressed is perfectly natural and does not greatly disturb me. Admittedly a very thorough analysis of all the financial and economic phases of the proposed plan must be made before it or any other measures of such heroic proportions can be taken. What is most important is that something be done on a scale sufficiently large to guarantee the financial recovery of the railroads.

LEON CAMMEN.

New York, N. Y.

Comments on August "Mechanical Engineering"

TO THE EDITOR:

I note the increasing number of vague articles on economic planning, such as that by Professor Shepard in the August issue. I have made specific recommendations for stabilization which involve his five points, and these recommendations have been sent to the American Engineering Council by way of criticism of the report by the Committee on the Relation of Consumption, Production, and Distribution.[2] I have further pointed out the necessary line of action for securing rapid and certain recovery from the present depression. These plans have been approved by certain economists.

The principles of stabilization of credit, which I have laid down, cover the points raised by A. E. Kittredge on the percentage of product to labor. The second principle, which requires limitation of capital investments to capital only slightly in excess of that necessary, must result in the accumulation of excess funds seeking investment whenever wages go too low. This very appearance of excess funds for investment is in itself a warning that wage scales and payrolls must be adjusted. Such excess funds, refused investment excepting in new projects, must tend to reduce the value of such funds for earning interest and to a certain extent favor increased use for consumption. Excess competition produced by excess capacity has resulted in distribution and manufacturing wastes. The second stabilization principle aims at removing these losses by cutting down on the cause of them.

I am inclined to agree with S. D. Mitereff that wide-spread distribution of the article, "The Balancing of Economic Forces," is highly desirable. However, it is important that the publication should include also the discussion and criticism which it evoked. Though a most commendable undertaking, the Committee produced a paper with a number of real weaknesses which should be clearly recognized.

The letter of J. E. Bullard is particularly commendable. I have written along closely parallel lines, and have particularly

[2] Printed in MECHANICAL ENGINEERING, June, 1932, p. 415, under the title, "The Balancing of Economic Forces."

recognized the necessity for securing cooperative action in securing increased payrolls and improved business, for without such action, guaranteeing reasonably general participation in purchasing, there can be no large or important departure from individualistic methods which dictate, according to the best of laissez-faire philosophy, further important and continued retrenchment in the face of the present situation. Characterization of the public's point of view by the term "unreasoning fear" is grossly incorrect. The public is merely following, in its own affairs as a group of independently acting individuals, the methods adopted by the independently acting business men who precipitated the real depression.

The business man wants orders. We all have increasing needs which must be met some time, the sooner the better. Yet unless a large amount of buying power is coordinated to act as a unit in placing orders, there can be no assurance that enough orders will be placed to secure substantial business recovery. That is the problem in a nutshell. Recovery can be had any time we are willing to secure the necessary coordination of buying power. It could have been had six months after the depression set in if the manufacturers had maintained payrolls as well as wages. Merely to maintain wages in the face of wide-spread cuts in time and employment is to do lip service to the plea of the President to maintain buying power. We have lost nearly three times, certainly twice, what our share of the European war cost through failure to act according to the needs of the situation.

The importance of certain potential markets for equipment that is becoming more and more necessary to the efficient carrying on of capacity operations is indicated by the somewhat exaggerated case of the railroads. They are suffering from inability to earn the full return allowed by law and the building up of surpluses, and also from competition which has reduced passenger traffic nearly 30 per cent and freight considerably less, based on revenues. The number of locomotives in service is about 60,000. At a 20-year life, replacements should number about 3000 a year, or somewhat less, allowing for real loss of business and the reduction in number of locomotives necessary for a given service. Yet the average replacements for Class I railroads, which would include the vast majority of the railroad mileage, has been 1159 for the years 1926 to 1931, both inclusive. It would appear that replacements are behind by five to eight thousand locomotives for this period alone, and I have not considered other equipment. If the railroads and the larger industries were to go out tomorrow and place orders for the machinery, equipment, repairs, and the like necessary for economical operation at even 80 per cent of normal demand, the impact of those orders should be sufficient to produce recovery of more than that amount. Such recovery would be normal and permanent as business goes. The important thing is to secure a return to normal employment of labor. Once accomplished, business can hold its gains, business and individuals can wipe out their indebtedness, meet the various budgetary demands, dispense with relief, and lay the foundation through industry of a new development of prosperity. Whether they will be able to maintain that prosperity will depend upon the handling of the various problems which now seem so to press for solution. But proper organization for the meeting of our potential demands, particularly in industry, should be sufficient to start the process of recovery and insure its normal progress.

Whenever I protest against vagueness, I am prepared to offer definite constructive proposals.

Edward Adams Richardson.[3]

Bethlehem, Pa.

[3] Jun. A.S.M.E.

Tolerances for Cylindrical Parts and Limit Gages

A STATEMENT of policy to guide the work which they are about to undertake has been unanimously approved by the members of Sub-Committee No. 1 of the Sectional Committee on Allowances and Tolerances for Cylindrical Parts and Limit Gages, of which R. E. W. Harrison, of Cincinnati, is chairman.

The scope of the project with which this committee is charged is the bringing into line with present-day practices of the system of fits and tolerances tentatively approved by the American Engineering Standards Committee, now the American Standards Association, in December, 1925. The standards adopted by this original committee proved to be slow of adoption by industry in this country, and some differences of opinion in the engineering profession have grown up which require expression, and which, if proved worthy, will be embodied in a revised system.

The members of the committee recognize the magnitude and importance of the task with which they are confronted, but believe that with the active cooperation of all parties concerned a standard system can be evolved which will be nationally acceptable.

In its statement of policy the committee recognizes that experience has taught the futility of recommending a system that cannot be reasonably adhered to either economically or mechanically. It agrees, therefore, that the recommendations when eventually submitted shall be characterized by the extreme simplicity of their presentation. The committee further recognizes that the recommendations which it will bring forth will be put into operation by practical men and should therefore be of such a nature as to be readily endorsed by them as well as by the manufacturers of reamers and gages, and by tool supervisors, designers, production engineers, and inspectors. The committee therefore concludes that while theoretical considerations cannot be ignored, they must not become a part of the recommendations if they interfere with the practicability of the scheme proposed. The committee, in its statement of policy, further recognizes the fact that in the past systems have been recommended that were based on the assumption that it is possible to buy reamers, drills, and machine tools which will produce work of absolute accuracy, irrespective of the ratio of length to diameter. The committee realizes, therefore, that its recommendations must be made in the light of the knowledge that tolerances are inseparable from the instruments that will have to be used to produce its scheme of fits. Another principle laid down in the statement of policy is that the recommendations shall be for American industry and suited to American methods of manufacture, and that they will be influenced by foreign practice only in those phases in which the experience of foreign engineers can be utilized in the furtherance of American methods of manufacture.

The statement concludes by expressing the belief that the whole-hearted support of the technical press is essential to the success of the project.

The personnel of the committee, in addition to R. E. W. Harrison, Chairman, is as follows: F. E. Banfield, Works Manager, Saco-Lowell Shops; F. O. Hoagland, Master Mechanic, Pratt and Whitney Company; Col. J. O. Johnson, Chief, Gage Section, U. S. A. Ordnance Department; P. V. Miller, Manager, Small Tool Dept., Taft-Pierce Mfg. Co., D. W. Ovaitt; E. Pugsley, Factory Manager, Winchester Repeating Arms Co.; and H. L. Van Keuren, Van Keuren Co., Watertown, Mass.

BOOK REVIEWS AND LIBRARY NOTES

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E., and the A.I.E.E. It is administered by the United Engineering Trustees, Inc., as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets, and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Raise Wages

REVIEWED BY WALTER RAUTENSTRAUCH[1]

RAISE WAGES! By A. G. McGregor. London General Press, London, 1932. Paper, $5^1/_2 \times 8^1/_2$, 60 pp., 2s 6d.

WHEN one notes on the cover page of a book, as is the case in this instance, the quotation from the contents, "Increasing the pay of the workers is the only sound means of reversing deflation and would be the stepping stone to a new era," he is surprised that any one who has made a study of our complex economic system should propose that there is *any single factor* of the many which operate to condition our economic trend and status which, if adjusted, could thus bring all others into harmonious relation and stabilize a bewildered world.

By selecting this "key note" for the cover page, the author has apparently misinterpreted himself, for the real purpose of the text seems to be to suggest an alternate raising and lowering of wages in adjustment to an agreed level of commodity prices. The specific proposal is for the creation of a "governmental authority" acting for wages, somewhat after the fashion in which our Federal Reserve Board adjusts the rediscount rates. In noting the duties of this "authority," the author states: "When wholesale commodity prices are tending to sag below the level agreed upon, which would mean that currency was tending to have a greater purchasing power than the level agreed upon, this authority would merely recommend a small percentage increase in wages and salaries with the understanding that it would apply equitably and orderly to every employee throughout the nation, and thus the purchasing power of currency would be slightly reduced, with a decrease in saving and an increase in spending and justice to all. In the same way if commodity prices are tending to rise above the level agreed upon, the purchasing power of currency would be slightly increased through a slight decrease in wages and salaries of all employees, automatically bringing a little less spending and a little more saving, with justice to all concerned."

In spite of his referring to this proposal as "the only sound means of reversing deflation," the author suggests further for the United States that it go off the gold standard; rediscount sound commercial paper at low interest rates through the Treasury; and adjust the exchange rate of its currency to preserve a proper balance between its exports and imports.

Some chapters are devoted to a criticism of the gold standard and to the suggestion that governments operate a managed currency after the manner suggested by Irving Fisher in "Stabilizing the Dollar," presumably by fixing the purchasing power of bank notes in adjustment to an agreed system of wholesale price of commodities indexing. In fact, the author's thesis is that economic stability is to be attained by discarding the gold standard, operating a system of managed currency, adjusting wages as above recited, and eliminating protective tariffs.

It is impossible to discuss adequately within the limited scope of a review all the problems which these proposals raise. Nor can a book of such small proportions present a series of convincing arguments for so complicated a problem. One immediately thinks of the works of Cassel, Weber, Pigou, and others in the matter of unemployment as affected by a high wage level, and of Hobson and Lederer, who argue just the opposite. Has the author been influenced by the fact that in England post-war unemployment has been associated with those industries in which the wages are low and those which have prospered have paid relatively high wages? It is not fair to the author to lay too much stress on "Raise Wages," for his real proposal is to *adjust* wages. But in adjusting wages to prices we must realize that price movements always come first before wage adjustments, by our present system. Is it therefore desirable to anticipate this movement in wages by the "suggestions" of a designated authority? Can a system be improved if its observed oscillations be adjusted to greater frequencies?

One must agree with the author that the gold standard as operated at present leaves much to be desired and that any staying of the operation of the law of comparative advantage by the device of a protective tariff hampers the free movement of trade and stagnates the world's markets. But at the same time one feels that a quantitative study of the problems involved is the best engineering approach to the acceptance of any proposals for their adjustment or elimination. Unfortunately the discussion of these problems is so everlastingly bound up in the political policies and the propaganda of contending groups that one doubts the very statistical evidence put forward for the ostensible purpose of clarifying the issue. It seems almost as if we need to go deeper into the question and first establish a more wholesome social philosophy before we can concentrate public opinion on the objective solution of the problems of economic stability. I am reminded of the practice of the ancient Greeks in the treatment of their sick, which, it will be recalled, was to take them to the market place where all who passed by might prescribe a remedy. It remains for some philosopher who views this poor, sick economic world on its cot in the market place to suggest that the frequent pains in the head and impaired vision are due to its way of life.

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Perhaps we have studied this problem so long that we know too many ways by which it cannot be worked. If we could organize ourselves on an experimental basis (like the Russians, for example) we might find how good we are at "guessing" at solutions. As Mark Twain said about the weather, everybody talks about it, but nobody does anything about it.

This book is interesting; has some emotional appeal; but like many brochures of this character, lacks some convincing evidence. The questions raised are interesting speculations. One cannot imagine, however, a citizenship of any country which is so docile that the "suggestion" of an "authority" to raise or lower the general wage level would be complied with. The machinery of society is too complicated to hope for any simple procedure for adjustment as this book suggests.

Applied Gyrodynamics

Applied Gyrodynamics—for students, engineers, and users of gyroscopic apparatus. By Ervin S. Ferry, Professor of Physics in Purdue University. John Wiley & Sons, New York, 1932. Cloth, 6 × 9 in., 272 pp., 219 figs., $4.

Reviewed by J. P. Den Hartog[2]

The preface of this book starts as follows: "Gyrodynamics is the brain child of the pure mathematician. From the beginning it was hedged about by a wall of differential equations. Some engineers and physicists have broken through this wall and have elicited the aid of gyrodynamics in producing marvels greater than those of fabled Daedalus." And further: "The purpose of the present book is to bring gyrodynamics out from behind the integral signs and to present it to the acquaintance of engineers and students having the mathematical equipment of the ordinary graduate of engineering or physics."

In this purpose the author has succeeded admirably. The book opens with a review of the elementary laws of dynamics presented in a clear and concise manner. The properties of the gyroscope are then discussed in a general way, and finally a great number of practical applications are given in detail. The usual examples of dynamics textbooks, such as the torpedo, ship stabilizer, etc., naturally appear, but in a much clearer manner than the reviewer has ever seen before. Besides these, many devices are described which have not as yet found their way into textbooks; for example, five different constructions of gyro compasses, an apparatus for keeping a ship on a straight course, the automatic airplane pilot, devices for gun-fire control on battleships, and a device for keeping a camera in the correct position in an airplane making a photographic survey. The amount of mathematics is reduced to a necessary minimum, while on the other hand the book has not degenerated into a mere technical description of apparatus.

It is warmly recommended to any reader interested in mechanics generally. It is very suitable also as a textbook for a graduate course in the subject for mechanical-engineering students.

Books Received in the Library

ATM Archiv für Technisches Messen. Nos. 4–12, November, 1931–June, 1932. R. Oldenbourg, Munich and Berlin. Paper, 9 × 12 in., illus., diagrams, charts, tables, 1.50 r.m. each. This compendium of measuring instruments and methods is intended to cover, in five volumes, the whole field of technical measurements. Parts are issued monthly and may be bought singly. Each part contains concise reviews, from two to four pages long, of about a dozen instruments or methods, accompanied by references to the sources from which the account was compiled. The articles are provided with classifications by the Decimal System and a special system, by either of which they may be filed in loose-leaf binders.

Ausgewählte Schweisskonstruktionen, Vol. 3. Rohrleitungs- und Behälterbau. By Holler and A. D. Fink. V.D.I. Verlag, Berlin, 1932. Cloth, 9 × 12 in., 88 pp., illus., diagrams, 12.50 r.m. An atlas of 88 plates illustrating the application of modern methods of welding in the construction of containers and pipe lines. Photographs and drawings present a wide variety of apparatus, selected to illustrate the advantages of welding in the manufacture of equipment for chemical factories, steam plants, etc. Explanations of the plates are given in English.

Die Dampfturbinen, Vol. 3. (Sammlung Göschen 716.) By C. Zietemann. Walter de Gruyter & Co., Berlin and Leipzig, 1932. Cloth, 4 × 6 in., 144 pp., illus., diagrams, charts, tables, 1.62 r.m. The final volume of this little textbook first discusses the methods of regulation for steam turbines and the design of governors. A second section reviews the turbines now on the market. The fourth section describes back-pressure, bleeder, exhaust-steam, and other turbines for special purposes. The final section is devoted to condensers.

Elektrische Industrieöfen für Weiterverarbeitung. By V. Paschkis. Julius Springer, Berlin, 1932. Cloth, 6 × 9 in., 305 pp., illus., diagrams, charts, tables, 31.50 r.m. The aim of this work is to present a systematic, comprehensive work on the electric furnace which will meet the needs of designers and users. The principles of furnace design, methods of regulation, furnace materials and the economics of the electric furnace are considered, and the construction of furnaces for various purposes, and of their elements is treated at length. The book is limited to resistance furnaces, and explicit directions for designing these are given.

Forschungsheft 355. Verdunstung und Wärmeübergang an senkrechten Platten in ruhender Luft. By R. Hilpert. V.D.I. Verlag, Berlin, 1932. Paper, 8 × 12 in., 22 pp., illus., diagrams, charts, tables, 5 r.m. The author reports upon investigations of evaporation in still air, undertaken especially to obtain experimental proof of the theory of Lewis, that the quotient obtained by dividing the coefficient of heat transfer by the coefficient of vapor diffusion equals the specific heat of the gas. Extensive tests with water, benzene, toluene, and other hydrocarbons showed close agreement with the theory.

Das Härten des Stahles. By F. Reiser and F. Rapatz. Eighth edition. Arthur Felix, Leipzig, 1932. Cloth, 6 × 9 in., 200 pp., illus., diagrams, charts, tables, 12 r.m. This manual of heat treating is intended for the toolmaker rather than for the skilled metallurgist, and gives clear, definite directions for hardening, tempering, and annealing steel for all usual purposes. The theoretical principles are explained, methods and equipment are described, the treatment of various steels and tools is explained, and methods of testing are given. This edition is entirely rewritten.

A History of the Oil Engine. By A. E. Evans, with foreword by Sir D. Clerk. Sampson Low, Marston & Co., London, 1932. Cloth, 6 × 9 in., 336 pp., illus., diagrams, charts, 25s. The book summarizes the more important incidents in the development of the internal-combustion engine toward the direct-injection heavy-oil engine of today. The history beings with Huyghens' gunpowder engine of 1680 and continues to 1930. Both general developments and the evolution of the various parts of the engine are discussed critically, the result being a review of past work full of interest to students of gas-engine design. The numerous plates add to the usefulness of the book, and there is an index of important British patents.

Industrial Management. By E. C. Robbins and F. E. Folts. McGraw-Hill Book Co., London, 1932. Cloth, 6 × 9 in., 757 pp., diagrams, charts, maps, tables, $5. In this book the "case system" is applied to a beginning course in industrial management. One hundred and seventeen cases are given which present problems involving concepts that underly present-day management, such as specialization, diversification, and integration, and also the application of these fundamentals to managerial control of raw materials, labor, plant, and equipment. The course aims to train the student to realize the significant facts in a managerial problem and to use them as the basis for reasoned judgments.

IS-Diagramme für Verbrennungsgase und Ihre Anwendung auf Die Verbrennungsmaschine. By W. Pflaum. V.D.I. Verlag, Berlin, 1932. Paper, 9 × 12 in., 45 pp., illus., tables, charts, 17 diagrams in pocket, 7.90 r.m. In the first part of this book entropy-heat diagrams similar to the Mollier diagrams have been developed for the fuels

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ordinarily used in internal-combustion engines—gasoline, benzene, coke-oven gas, illuminating gas, air gas, blast-furnace gas, and coal. These tables hold for pressures from 0.1 to 200 atmospheres and 0 to 3000 C. Supplementary diagrams for the amount of air required and for the combustion volume and combustion heat are included.

In part two the processes that best utilize the available energy are established for the various types of two-cycle and four-cycle engines. Theoretical thermal efficiencies and mean piston pressures, calculated with the new entropy-heat diagrams, are given for all cases that usually occur in practice.

OSKAR VON MILLER. By W. von Miller. Verlag F. Bruckmann, Munich, 1932. Cloth, 6 × 9 in., 184 pp., illus., 5.50 r.m. From the year 1881 onward, Dr. von Miller has been closely connected with the development of the power resources of Bavaria and of electrical undertakings in Germany. He organized the Munich Electrical Exposition of 1882, participated in the formation of the German Edison Company in 1883, and has been active, as engineer or consultant, in most important electical undertakings in Germany. In later life he has become widely known as founder and director of the German Museum of Science and Industry. From autobiographical notes, letters, and addresses his son has compiled a highly interesting account of the man and his work.

PRINCIPLES OF REFRIGERATION. By W. H. Motz. Third edition. Nickerson & Collins Co., Chicago, 1932. Cloth, 6 × 9 in., 1019 pp., illus., diagrams, charts, tables, $7.50. The fundamental principles underlying the operation of ice-making and refrigerating machinery; the properties of the usual refrigerating media; the design, construction and operation of the apparatus; and the more important applications of refrigeration are discussed in this work in a practical, non-mathematical way. The book has been adopted by the National Association of Practical Refrigeration Engineers for study in its national lecture courses. This edition has been rewritten and considerably enlarged.

REFRIGERATING DATA BOOK AND CATALOG. First edition. 1932–1933. American Society of Refrigerating Engineers, New York, 1932. Leather, 6 × 10 in., 480 pp., 120 pp. cat. information, illus., diagrams, charts, tables, $3.50. The basic data of refrigeration engineering are brought together in this volume, which will be welcomed as a convenient encyclopedia of current practice. The various topics have been treated by specialists, with the assistance of an advisory committee appointed by the Society. Principles, equipment, and uses are all discussed.

SAILING SHIPS. Their History and Development, as Illustrated by the Collection of Ship-Models in the Science Museum, Part 2. Catalogue of Exhibits. By G. S. L. Clowes. H. M. Stationery Office, London, 1932. Paper, 6 × 10 in., 2s. 6d. The first part of this work appeared in 1930 and dealt with the historical development of sailing ships. The concluding part, now presented, is a carefully annotated catalog of the models in the Museum, accompanied by thirty-seven plates which present the more important exhibits. The collection is an important one, and the catalog is a fine piece of work, of interest to every student of shipbuilding.

SUPERHEAT ENGINEERING DATA. Seventh revised edition. Superheater Co., New York and Chicago, 1932. Leather, 5 × 7 in., 253 pp., diagrams, illus., charts, tables, $1. A useful collection of rules, formulas, numerical data, and other information frequently wanted by steam engineers and power-plant operatives interested in superheating. In addition to the general data, the products of the publisher are described and their use illustrated by a variety of typical installations.

SYMPOSIUM ON RUBBER, held at Cleveland, Ohio, March 9, 1932. American Society for Testing Materials, Philadelphia, 1932. Paper, 6 × 9 in., 160 pp., illus., diagrams, charts, tables, $1.75. The papers here presented deal with the manufacture of rubber products and the properties of rubber as an engineering material. Among the topics discussed are the properties of crude and reclaimed rubber, vulcanization, compounding, reinforcing materials, the flexing of rubber products, shock and vibration properties of rubber, deterioration under friction, resistance to water and chemicals, electrical characteristics and uses as an adhesive.

TECHNICAL TERMS IN THE TEXTILE TRADE. Vol. 2. General Terms. By E. Midgley. Emmott & Co., Ltd., Manchester and London, 1932. Cloth, 5 × 8 in., 259 pp., charts, tables, 12s. 6d. The first volume of this dictionary appeared in 1931 and defined the technical terms applied to cloth. The present book supplements that work by defining and explaining the materials used in making cloth and the processes that precede and follow cloth making. The textile raw materials are defined and described, and their sources given. The processing into yarns is dealt with, and the terms used in sorting, preparing, spinning, and in weaving, dyeing, and finishing are given. The definitions are full and explicit.

TEXTBOOK OF METALLURGICAL PROBLEMS. By A. Butts. McGraw-Hill Book Co., New York and London, 1932. Cloth, 6 × 9 in., 425 pp., illus., diagrams, charts, tables, $4. This book resembles "Metallurgical Calculations" by the late Prof. Joseph W. Richards and is, to a certain extent, a supplement to it, as it extends further in certain directions and contains new and more accurate numerical data. Its main purpose, though, is to fill the need for a textbook with a graded treatment of the subject, suited for use in engineering courses, rather than to provide a handbook for the practicing engineer. The course offers a thorough introduction to the problems that arise in metallurgy and to the methods of solving them.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS. Twenty-second editions. Thomas Publishing Co., New York, 1931–32. Cloth, 9 × 12 in., illus., $15. This directory lists, under products and firm names, American manufacturers and primary sources of supply in all industries. In addition it lists trade names and brands, banks, boards of trade, and other commercial organizations, and trade papers. In comprehensiveness and completeness it is unequalled by any other guide to purchasing.

WASSERBAULICHE MODELLVERSUCHE zur Klärung der Abflusserscheinungen beim ABSCHLUSS der ZUIDERZEE ausgeführt im Flussbaulaboratorium der Technischen Hochschule zu Karlsruhe. (Rapporten en Mededeelingen Betreffende de Zuiderzeewerken, No. 3.) By T. Rehbock. The Hague, Algemeene Landsdrukkerij, 1931. Cloth, 7 × 10 in., 282 pp., illus., diagrams, charts, tables, maps, 17 r.m. From 1922 to 1930 the Hydraulic laboratory of the Karlsruhe Technical High School was occupied with model study of problems connected with the twenty-mile dam which is the keystone of the Zuider Zee reclamation project and the sluiceways in the dam through which the surplus water will be discharged into the sea. In the present volume the director of these investigations presents a general account of the more important ones and of the major conclusions from them. Both these conclusions and the descriptions of the methods of applying research on models to problems of hydraulic flow will be useful to students of the movement of water.

WESTERN AND ATLANTIC RAILROAD OF THE STATE OF GEORGIA. Compiled by J. H. Johnston. Public Service Commission, Atlanta, Ga., 1932. Leather, 6 × 9 in., 364 pp., illus., charts, tables, maps, $5. This volume traces the history of a state-owned railroad from its inception ro the present day and describes its varying fortunes under state operation and in the hands of successive lessees. The volume is based upon official records and is primarily intended to supply legislators of Georgia with a convenient record of essential facts. It is also an interesting addition to the history of American railroads.

WINDEN UND KRANE. Aufbau, Berechnung und Konstruktion. By R. Hänchen. J. Springer, Berlin, 1932. Paper, 8 × 11 in., diagrams, charts, tables, No. 3, 220 pp., 7.75 r.m.; No. 4, 306 pp., 8 r.m. These brochures are parts of an unusually complete and thorough treatise on the design and construction of hoists and cranes, which should be valuable as a reference work for the designer. In section three, lifting tackle of all kinds, electrical equipment and stationary and portable hoists are treated. Section four is devoted to traveling crabs and to the general principles of crane construction.

WIRTSCHAFTLICHER KONSTRUIEREN—BILLIGER GIESSEN! By R. Lehmann. V.D.I. Verlag, Berlin, 1932. Paper, 6 × 9 in., 48 pp., illus., diagrams, tables, 4.20 r.m. This booklet discusses the making of machine-molded castings and shows by numerous examples how the cost of castings and subsequent machinery can be reduced by attention to certain principles in their design. The limits of application of various molding machines are discussed, and their advantages and disadvantages explained. Points that affect the design of machine parts are brought out. The book is intended to assist the designer to design in line with foundry requirements.

ZAHNRÄDER, Part 1. (Werkstättbücher, No. 47.) By G. Karrass. J. Springer, Berlin, 1932. Paper, 6 × 9 in., 60 pp., diagrams, charts, tables, 2 r.m. This concise book on the design of gears forms one of a series upon shop practice, intended for machinists and students. The aim is to present the subject scientifically and practically, upon the basis of current practice, without complicated mathematics.

CURRENT MECHANICAL ENGINEERING LITERATURE

Selected References From The Engineering Index Service

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AERIAL TRANSPORTATION

Electric Communication. Wire Communication Aids to Air Transportation, H. H. Nance. Bell System Tech J v 11 n 3 July 1932 p 462–76. Wire communication facilities in general use today, both by Government and transport companies, as aids to air transportation; transmission of weather reports; plane dispatching and other service; teletypewriter circuit layout; teletypewriter equipment; radio interference. Bibliography.

AIR COMPRESSORS

Automatic Control. Die Automatisierung elektromotorischer Betriebe in der Pressluftwirtschaft, R. Rueckert. Elektrizitaet im Bergbau v 7 n 4 July 1932 p 72–80. Automatic control of electric motor drives in compressed-air practice; previous measures for improvement of compressed-air operation; automatic control of reciprocating compressors; technical details and operating data.

Rotary. Semi-Portable Rotary Compressor. Engineering v 134 n 3469 July 8 1932 p 51. Set manufactured by Swiss Locomotive and Machine Works, Winterthur, Switzerland, is air-cooled; electric motor is of squirrel-cage type operated by auto-transformer starter; compressor is of two-stage type and should be of particular value for constructional work, as its light weight enables it to be readily moved from floor to floor as work progresses.

AIR CONDITIONING

Methods. Introduction to Air Conditioning, J. C. Fistere. Arch Forum v 57 n 2 Aug 1932 p 167–74. Purpose of air conditioning; cooling methods; methods of dehumidification; cleaning and distribution; residence conditioning; controlling factors; restaurants and shops; theaters; recirculation; insulation; cost.

AIR PREHEATERS

Balance. Thermal Balance of Air Preheaters of Large Steam Generators, M. W. Travers. Engineering v 134 n 3473 Aug 5 1932 p 161–3. Experiments made at request of Underfeed Stoker Co. at Neasden and Leicester power stations; first tests carried out in one of six pulverized-fuel fired tri-drum water-tube boilers of 89,000 lb per hr normal evaporation working at steam pressure of 290 lb per sq in.; unit at Leicester is tri-drum water-tube boiler of 120,000-lb per hr normal evaporation, working at pressure of 375 lb per sq in.

Economy. Lohnt sich ein Lufterhitzer auch fuer Kleinkraftwerke, Storch. Waerme v 55 n 26 June 25 1932 p 440–1. Economy of air preheaters for small power plants; it replaces special units for peak-load equalization; by preheating combustion air, increase in flexibility of furnace and better combustion of coal is achieved; it permits utilization of low-grade coke breeze and refuse in municipal plants; advantages of steel jackets for small air heaters and economizers over bricking in; increase of efficiency of Diesel waste-heat utilization.

Plate Type. Plate Type Air Heaters. Engineer v 154 n 3995 Aug 5 1932 p 142. Air heaters made by Babcock and Wilcox for Dunston power station at Newcastle-upon-Tyne, to be installed in conjunction with two-stage boilers; they are of cross-flow plate type, and consists of one or more single elements of plates, alternate edges of which are so bent and welded together as to form vertical gas passage and horizontal air passages.

AIRPLANE ENGINES

Pobjoy. Light-Weight Radial Engine. Aircraft Eng v 4 n 41 July 1932 p 180. Design and specifications of 7-cyl air-cooled R engine of geared, dry sump type; bore $3^{1}/_{32}$ in.; stroke of $3^{27}/_{64}$ in.; weight with airscrew hub 135–140 lb; maximum power at 3300 rpm, 85 bhp; weight per hp 1.87 lb; fuel consumption per hr at 0.9 full throttle, $4\frac{1}{2}$ gal.

Supercharging. Les compresseurs volumétriques à pistons, S.E.B.I.A. Aéronautique v 14 n 157 June 1932 p 163–9. Design and operating characteristics of opposed-piston 2-cyl compressors for airplane engines of 95 and 500 hp; output of 11.44 cu m, respectively, 64.15 cu m at 1700 rpm; weight of 11 and 40 kg.

Testing. New Aircraft-Engine Airworthiness Requirements are Proposed. Automotive Industries v 67 n 2 July 9 1932 p 44–6 and 57. Tentative draft of airworthiness requirements for engines issued by Aeronautics Branch of Department of Commerce with particular regard to tests.

AIRPLANES

Design. How Many Engines? F. T. Courtney. Aviation v 31 n 8 Aug 1932 p 337–9. Comparison of reliability and efficiency of ship equipped with 2, 3, and 4 engines.

Military. New Aeroplanes at R.A.F. Display. Aeroplane v 42 n 25 June 22 1932 11 p between p 1126–43; see also Flight v 24 n 26 June 24 1932 p 544–5. Specifications of principal types of equipment of Royal Air Force including fighter, bomber, torpedo plane, and troop-carrier.

Passenger. Transport Airplanes, Then and Now, E. P. Warner. Aviation v 31 n 8 Aug 1932 p 323–7. Historical review of development of principal types of planes for mail and passenger transportation; comparison of European and American trends.

Propellers. Les hélices et leur adaptation sur l'avion, R. Pris. Aérophile v 40 n 6 June 1932 p 177–81. Calculations in selecting suitable propellers for given airplane and engine combinations.

Stability. Stabilité automatique des avions, F. Haus. Aéronautique v 14 n 156 and 157 May 1932 p 139–44 and June p 171–9. Mathematical formulation of principal factors affecting static and dynamic stability with particular regard to pitching moments, influence of propeller, damping, etc. (To be continued.)

Wings. Avions à surface variable, J. Lacaine. Nature (Paris) n 2883 June 15 1932 p 541–6. Increase in maximum and minimum speed by variation of wing area with particular regard to designs by Bille, James, Gérin, de La Fournière, and Makhonine.

ALLOYS

Bearing Metals. See *Bearing Metals.*

Steel. Haertbarkeit und Anlassbestaendigkeit von Staehlen mit schwerloeslichen Sonderkarbiden, E. Houdremont, H. Bennek, and H. Schrader. Archiv fuer das Eisenhuettenwesen v 6 n 1 July 1932 p 24–32 (discussion) 32–4. Hardening properties and tempering strength of steels with only slightly soluble special carbides; increase of hardness and strength with elevated quenching temperature; dispersion hardening by special carbide as cause of tempering, cutting, and heat resistance; results of investigation of vanadium steel.

Steel Used in Making Die Blocks, B. Thomas. Heat Treating and Forging v 18 n 6 June 1932 p 353–6. Selection of properties of steel for principal types of dies including hot and cold dies, forging and stamping dies.

AUTOMATIC CONTROL

Thrustors. How Thrustors Are Used, R. F. Emerson. Mill & Factory v 10 n 6 June 1932 p 25–7. Within past year or so, self-contained hydraulic devices of various sizes called thrustors have been successfully applied to many different industrial applications; by means of these rotary motion of motor is efficiently converted into smooth straight line thrust in one direction.

AUTOMOBILE ENGINES

Lubrication. Frequent Crankcase Draining Cheap Insurance Against Damage to Motors, W. C. Bauer. Nat Petroleum News v 24 n 25 June 22 1932 p 36 and 38–9. Experimental investigation of progressive deterioration of motor oil; causes of dilution, saturation with grit, accumulation of acidity, and emulsification.

AUTOMOBILES

Axles. Ford Axle Shafts Heated and Forged Automatically, E. F. Ross. Steel v 91 n 5 Aug 1 1932 p 23–5 and 28. Forging methods and equipment with particular regard to elevated-type continuous electric heating furnace, motor-driven forging machine and conveyors.

Bearings. Fundamentals of Automotive Lubrication, H. C. Dickinson and O. C. Bridgeman. Soc Automotive Engrs—J v 31 n 1 July 1932 p 278–82 and 304. Characteristics controlling performance of lubricants in journal bearings, ball and roller bearings and gears; equations for journal bearings operating under

various conditions of design, lubrication, friction and heat dissipation; neither ZN/P nor PV alone is adequate as measure of power dissipated by bearing.

TRANSMISSIONS. Free-Wheeling Devices and Their Control, A. M. Wolf. Soc Automotive Engrs—J v 31 n 1 July 1932 p 265–77. Design and operating principles of devices now in use on American cars; experiences of Studebaker Corp and other manufacturers, showing how present designs of roller clutch have evolved; lubrication of free-wheeling transmissions; combination unit to include free-wheeling, service brake and sprag.

Free-Wheeling Rolls Must Withstand Severe Shocks, K. L. Herrmann. Machy (N. Y.) v 38 n 12 Aug 1932 p 881–5. Grinding, lapping, and heat treating operations of Bantam Ball Bearing Co., South Bend, Ind., making 25,000 free-wheeling rolls per day.

WELDING REPAIR. Automotive Repair. Oxy-Acetylene Tips v 11 n 7 July 1932 p 99–108. Examples of profitable application of welding bronze weld; weld with rod of similar composition; weld with high-test welding rod; solder; heating operations; and Haynes stelliting.

AUTOMOTIVE FUELS

GAS. European Experiments With Gas as Automobile Fuel, A. C. Blackall. Gas Age-Rec v 70 n 3 July 16 1932 p 72. Brief item on tests made in France, Great Britain, and Germany.

SYNTHETIC. Ueber die Bildung von Aromaten und Hydroaromaten aus ungesaettigten Verbindungen, J. Varga and I. Makray. Brennstoff-Chemie v 13 n 13 July 1 1932 p 248–9. Formation of aromatics and hydroaromatics from unsaturated compounds with pressure hydrogenation of cracked gasoline; investigation of lignite-tar cracked gasoline with about 50% unsaturated compounds and 28% aromatic hydrocarbons using method of C. C. Towne, which was found more satisfactory than that of Riesenfeld and Bandte. See also Engineering Index 1931 p 106 and 634.

BALANCING MACHINES

EQUIPMENT. Balancing Equipment, C. N. Fletcher. Automobile Engr v 22 n 295 July 1932 p 327–8. Design and operating principles of new Olsen semi-automatic machine for automobile work.

BEARING METALS

BRONZE. Ueber Blei-Zinnbronzen, ihre Konstitution, ihre Eignung und Verwendung als hochbeanspruchte Lagermetalle, B. Blumenthal. Metallwirtschaft v 11 n 26 and 27 June 24 1932 p 360–2 and July 1 p 374–5. Lead-tin bronzes, their constitution, their adaptability and use as highly stressed bearing metals.

BEARINGS

LUBRICATION. All Bearing Lubrication Is Pressure Lubrication. Power v 76 n 1 July 1932 p 22–3. Article based on paper by W. F. Parish and L. Cammen, previously indexed from various sources.

BLAST FURNACES

CHARGING. Steuerung von Hochofen-Begichtungsanlagen mit Kippkuebeln. Elektrotechnische Zeit v 53 n 29 July 21 1932 p 699–700. Electric control of blast-furnace charging equipment with tilting buckets.

BLOOMING MILLS

ELECTRIC EQUIPMENT. Bemessung der Geschwindigkeiten fuer die Hilfseinrichtungen neuzeitlicher schwerer Blockstrassen, E. Howahr. Stahl und Eisen v 52 n 29 July 21 1932 p 701–4 (discussion) 704–6. Measurement of speeds for auxiliary equipment of modern heavy blooming mills; charts and tables presented demonstrate how speeds of various auxiliary equipment are tested; starting time of electric motors; acceleration moments.

BOILER FURNACES

MANUFACTURE. Festigkeitseigenschaften einer hochwertigen Lichtbogenschweissung, G. Czternasty. VDI Zeit v 76 n 28 July 9 1932 p 679–82. Report on test to failure, by bursting, of electrically welded boiler 1.5 m in diam, 3.5 m long; deformation of boiler at pressures of 131 and 155 atm; bending tests and study of microstructure of material of longitudinal steams.

WATER-COOLED. Les chambres de combustion à parous froides augmententelles les imbrûlés, G. Bruhat. Chaleur et Industrie v 13 n 145 May 1932 p 339–46. Analysis of heat transfer phenomena with particular regard to possibility of increase in ash residues as consequence of cold walls.

BOILERS

CONTROL. Pushbutton Control Permits Centralized Boiler Operation, E. S. Bristol. Power v 76 n 2 Aug 1932 p 64–5. Pushbutton control of boilers under certain conditions may serve as substitute for full-automatic combustion control; to insure reliable operation equipment must be selected with particular attention to severe conditions of boiler-plant operation.

CORROSION. Solubility of Calcium Sulfate and Calcium Carbonate at Temperatures Between 182 and 316°C, F. G. Straub. Indus & Eng Chem v 24 n 8 Aug 1932 p 914–17. Results of investigation show that solubility of calcium carbonate and calcium sulphate decreases with increase in temperature.

FIRING. Berechnung des Verbrennungsvorganges bei der Verfeuerung von Gasgemischen, W. Baehren. Feuerungstechnik v 20 n 6 and 7 n 6 June 15 1932 p 81–5 and July 15 p 105–6. Calculation of combustion process in firing of mixed gas; factors governing calculation of gas mixtures consisting of blast-furnace and coke-oven gas on one hand, and of pulverized coal, blast-furnace, and coke-oven gas on other hand.

HIGH-PRESSURE. Official Trials of Sulzer Two-Drum Two-Bank Boiler for 510 Lb Per Sq In. Working Pressure. Sulzer Tech Rev n 2 1932 p 12–14. In chemical works J. R. Geigy A.-G., Grenzach, Switzerland, two-drum two-bank boiler for working pressure of 510 lb per sq in. gage (36 atm) and superheat temperature of 715 F (380 C) has been put into service; test results detailed in tables and curves.

Recent Developments in Boiler Engineering. Engineer v 154 n 3994 July 29 1932 p 109–10. Manufacture of water-gas-welded high-pressure boiler drums in use at Thyssen Works of United Steel Works at Muehleim-Ruhr, Germany; development of this process up to present day; new seamless rolling method for high-safety boiler drums.

PLATES. Nickel-Steels Resist Embrittlement, H. J. French and C. M. Schwitter. Iron Age v 130 n 2 July 14 1932 p 51–3 and (adv sec) 18. Some of less generally recognized characteristics of low-carbon nickel steels which make them valuable for use in boilers; increase in nickel content reduces aging embrittlement, as demonstrated by impact or slow bend tests on notched bars.

PULVERIZED-COAL. Kohlenstaubfeuerung fuer Flammrohrkessel, J. Thieme. Waerme v 55 n 27 July 2 1932 p 461–3. Pulverized-coal firing for fire-tube boilers; advantages lie in elimination of mechanical parts in combustion chamber and possibility of utilizing fine and pulverized coal with high gas content; design of plant is determined by nature of fuel used, pulverized or fine coal; economy is obtained by better fuel utilization and use of low-grade fuels.

TUBULAR. New Type of Boiler Increases Power-Plant Efficiency at Caron Spinning Co., K. C. Schmidt. Textile World v 82 n 1 July 1932 p 84–5. Hand-fired boiler was replaced with S & G steam generator, new type of low head-room, two-drum, bent-tube boiler unit with integral water walls; drums, instead of being placed across setting at right angles to center, are parallel to furnace and at one side; designed primarily for pulverized coal, gas or oil firing.

WATER-TUBE. Water-tube Vertical Boiler. Engineer v 154 n 3993 July 22 1932 p 93–4. Boiler manufactured by Fraser and Fraser is of vertical type, but includes number of inclined water tubes; these provide major part of heating surface; it is claimed boilers will produce from 6 to 11 lb of steam per hr per sq ft of heating surface and work with thermal efficiency of 70%.

BOLTS AND NUTS

EMBRITTLEMENT. Bolt Embrittlement, Harley-Mason. Engineering v 134 n 3471 July 22 1932 p 100. Embrittlement of bolts used on steam ranges; steels with low nickel content have been particularly unsatisfactory, but good results have been obtained with steels containing little molybdenum in addition to nickel; difficulty of working with bolts removed after service; it was decided to subject bolts to kind of impact test which might be caused by water hammer. Before Manchester Steam Users' Assn.

BORING MACHINES

BOSSES OF PROPELLERS. Boring Mills for Machining Bosses of Large Propellers. Engineer v 154 n 3991 July 8 1932 p 34–6. Machine built by George Richards and Co., is modification of makers' standard type of vertical boring mill; it accommodates work up to 17 ft diam with uprights in their forward or normal position and up to 25 ft diam when uprights are moved back to rearmost position.

OVAL. Boring Mill With Oval-Turning Attachment. Engineering v 134 n 3471 July 22 1932 p 94–6 and 98. Boring mill developed by Schiess-Defries A.G., Duesseldorf, for use in boiler shops; its leading feature is that, in addition to being suitable for machining peripheries of flanges for boiler ends, equipment is provided which enables oval openings, such as manholes, to be machined on both faces and inside surfaces.

VERTICAL. 17–25 Ft Vertical Boring Mill for Propellers. Engineering v 134 n 3470 July 15 1932 p 65–7. Boring mill developed by George Richards and Co. is capable of dealing with propellers for largest ships afloat; machine is modification of Richards standard-type vertical boring mill, and has uprights mounted on slides, so that they can be moved back with respect to table to deal with exceptionally large propellers.

BRIDGES

STEEL WELDING. Notes on Arc-Welding in Bridgework in Australia, W. D. Chapman. Iron and Coal Trades Rev v 124 n 3355 June 17 1932 p 995. Review of application of arc welding to repair and construction of railway and highway bridges in Australia; main applications in repair work; new railroad bridges; types of electrodes. Before Int. Assn. of Bridge and Structural Eng.

BUILDINGS

STEEL WELDING. Latest Structural Welding Developments, F. P. McKibben. Can Engr v 63 n 3 July 19 1932 p 15–17. Welding and building codes; arc welding of Pediatric Building, Boston; qualification tests for welders; preliminary estimates of welding; welding data for multi-story buildings; inspection of welded buildings.

CAR WHEELS

HEAT TREATING. Rim Toughening Treatment Improves Performance of Car Wheels. Steel v 91 n 6 Aug 8 1932 p 23–4. Heat treating methods developed by Carnegie Steel Co., Pittsburgh, increased mileage 100%.

CASE HARDENING

CARBURIZING. Role of Energizers in Carburizing Compounds, G. M. Enos. Am Soc Steel Treating—Trans v 20 n 1 July 1932 p 27–48 (discussion) 48–57. Effects of various materials as energizers in carburization and mechanism of carburization with reference to carbon transfer from compound to steel; carbonates are not needed as energizers; certain materials will act as catalysts in carburization and others will retard carburization; variations in case depth and carbon concentration as produced by different energizers.

CAST IRON

HIGH TEST. New Practice in Making High Test Iron Castings, H. H. Judson. Iron Age v 130 n 3 July 21 1932 p 103–4 and (adv sec) 20. In process described two cupolas are used and melts mixed; in one, charge is largely steel rails, while in other solfteuing materials are melted; low-carbon high-tensile iron thus produced is claimed to satisfy requirements for cylinders which must stand high pressures. Before Am. Foundrymen's Assn.

CHROMIUM PLATING

WEAR RESISTANCE. Chromium-Plating for Wear Resistance, W. Blum. Machy (N. Y.) v 38 n 12 Aug 1932 p 930–1. Results obtained by chromium-plating when applied for purpose of resisting wear on tools, gages, and machine parts. Before Franklin Inst.

COAL CARBONIZATION

CARBONIZATION. Carbonisation of Coal in Streams of Gases, J. H. Scholz and R. V. Wheeler. Fuel v 11 n 7 July 1932 p 244–53. Experiments to determine whether and if so, to what extent use of stream of gas during carbonization of coal at low temperature would affect quantity and character of oils and gases thus swept from retort as compared with yields ordinarily obtained.

COMBUSTION. Power Production With Iowa Coal, J. M. Drabelle. Power Plant Eng v 36 n 16 Aug 15 1932 p 626. Local coals with properly designed furnace and suitable equipment can be made to give lowest cost per 1000 lb steam; summary of boiler tests using several sizes of same coal. Before Nat. Assn. Power Engrs.

COKE OVENS

BLAST-FURNACE GAS. Towards Cheaper Steel. Soc Chem Industry—J (Chem and Industry) v 51 n 29 July 15 1932 p 612–14. Heat conservation at Normanby Park Works of John Lysaght, Ltd.; new installation of coke ovens so designed that they are heated efficiently with blast-furnace gas, this low-quality fuel being utilized to better advantage than has hitherto been possible; blast-furnace gas is obtained from adjoining blast furnaces and delivered to plant after washing in Theissen rotary washers.

COUPLINGS

FLEXIBLE. New Flexible Coupling. Engineer v 154 n 3992 July 15 1932 p 70. "Steel-Shaw" coupling made by Steele and Cowlishaw, comprises two cast-steel hubs, one keyed to each of

two shafts, driving and driven; actual coupling of two parts is provided by specially shaped keys of spring steel that fit into grooves.

CUPOLAS

PRACTICE. Zur Frage der Kohlungsvorgaenge im Kupolofen, K. Sipp and P. Tobias. Stahl und Eisen v 52 n 27 July 7 1932 p 662–4. Problem of carbonization in cupolas; observations during melting process on influence of carbon and silicon content of mixture, of coke, and of size of melting zone on carbon content of charge.

DAMS

FOUNDATIONS. Wire Saws Cut Rock Trench for Dam, C. B. Cornell. Construction Methods v 14 n 7 July 1932 p 38–9. Use of wire saws in cutting sides of cutoff trench for Prettyboy dam for department of public works of City of Baltimore; difficulties of channeling; wire-saw operation; calyx drill hole.

DIES

STAMPING. Compound Press Tools for Pole-Piece Stampings, S. A. Inscoe. Mech World v 92 n 2376 July 15 1932 p 57. Laminations of pole pieces require blanking and piercing; tool set described embodies both operations, and is designed to cut from 40,000 to 50,000 pieces between grindings; tools can be used in conjunction with standard die set to avoid effect of wear in press slides.

DIESEL ENGINES

BURMEISTER AND WAIN. New Double-Acting Two-Stroke Oil Engine. Engineer v 154 n 3992 July 15 1932 p 67–8 1 supp plate. Eight-cylinder 18,500 bhp unit with continuous max output of 22,000 bhp is being constructed at Burmeister and Wain's works for Copenhagen power station, and will be largest stationary oil engine in world; particulars of various installations and results obtained; low-pressure rotary blowers, which form part of plant.

CYLINDERS. Cylinder Wear in Diesel Engines, G. D. Boerlage and B. J. J. Gravesteyn. Brit Motor Ship v 13 n 150 Aug 1932 p 171–3. New chemical method mainly of use for purpose of ascertaining influence of fuel, lubricating oil, and load on cylinder wear; tables and graphs of results with test runs on two different fuels and influence of varying loads when using same fuel; equipment used.

FUEL INJECTION. Improved Compur Injection Pumps and Injectors Available Here, P. M. Heldt. Automotive Industries v 67 n 2 July 9 1932 p 41–3. Injection equipment for high-speed oil engines developed by firm of Friedrich Deckel of Munich, Germany; closed type injector with conical valve of differential type adjustable for pressures; constant-stroke type fuel pump feed controlled through by-pass valve with set screw.

HIGH-SPEED. Allen Railway Traction Diesel Engine. Ry Gaz v 57 n 3 July 15 1932 p 86–7. General design and constructional details of 6-cyl Allen high-speed airless-injection oil engine; adoption for locomotives; general arrangement of 150-bhp locomotive for Ford Works at Dagenham.

MARINE. Exhaust Boilers on Passenger Liners. Brit Motor Ship v 13 n 150 Aug 1932 p 186–7. Royal Mail Steam Packet Co. have decided to install exhaust-gas boilers on Asturias and Alcantara, details of which are given; installation on Carnarvon Castle; over £2000 saved yearly.

New Mirrlees Marine Engine. Brit Motor Ship v 13 n 150 Aug 1932 p 182–4. Reversible unit with interchangeable inlet and exhaust valves; engine develops 275 bhp at 225 rpm; fuel consumption 0.36 lb per bhp-hr; details of design and test-bed results.

MAYBACH. Maybach Airless-Injection Engines. Engineering v 134 n 3472 July 29 1932 p 118–20 1 supp plate. Two engines designed primarily for Diesel locomotive or rail-car use; in this application, they are of constant-speed type with electric transmission; 6-cyl model is practically converted form of older air-injection type; cylinders have 140 mm bore and 180 m piston stroke; output is 150 bhp at 1300 rpm; 12-cyl engine has many features in common with 6-cyl model, but separate cylinders are employed.

RELIABILITY. Cost and Reliability of Diesel Engine, G. Charlesworth. Power Plant Eng v 36 n 16 Aug 15 1932 p 635–6. Records of 10 representative stations ranging from isolated plants to peak load service; lack of skilled operators given as engine's worst handicap; Before Tenth Annual Conference of State Utility Commission Engrs. at Bur. Standards.

SULZER. Recent Developments in Sulzer Diesel Engine. Sulzer Tech Rev n 2 1932 p 1–11. Trends in modern design; technical features and materials testing, etc.

SUPERCHARGING. 6-Cylinder 1200 B.H.P. Supercharged Ruston Vertical Airless-Injection Oil Engine at Grantham for Ruston & Hornsby, Ltd., Lincoln, W. A. Tookey. Diesel Engine Users Assn—Report Mar 1931 6 p 1 supp plate. Tests on four-cycle engine converted to operate on Buechi system with particular regard to investigation of fuel and lubricating oil consumption; original rated output 850 bhp at 250 rpm.

DRILLING

INCREASED PRODUCTION. Increasing Drilling Production on Variable Products, B. Lockwood. Mech World v 92 n 2376 July 15 1932 p 49–50. By means described spindle drilling hours can be utilized to almost 100%.

ELECTRIC FURNACES

INDUSTRIAL. Elektrische Industrieoefen fuer Weiterverarbeitung, V. Paschkis. Berlin, Julius Springer, 1932 305 p illus diagrs charts tables. 31.50 rm. Systematic, comprehensive work on electric furnace to meet needs of designers and users; principles of design, methods of regulation, furnace materials, and economies of electric furnace are considered; furnaces for various purposes; explicit directions for designing resistance furnaces. Eng. Soc. Lib. N. Y.

MIGUET. Le four Miguet, S. Heuland. Société Française des Électriciens—Bul v 2 n 19 July 1932 p 688–707. Single-phase single electrode type furnace of Miguet described, with regard to its design, operation, and advantages; 9000-kw furnace operated with 7 men.

TRANSFORMERS. Ueber Einen Modelltransformator fuer einen induktionsofen, R. Kuemmich. Zeit fuer Elektrochemie v 38 n 7 July 1932 p 402–7. Design of model 3-kw, 50-cycle transformer for induction furnace to be used as demonstration object for instruction; equipment developed and designed at Stuttgart Institute of Technology.

ENGINEERING

EDUCATION. Engineering Education in Canada, E. G. Cullwick. Eng J v 15 n 7 July 1932 p 337–48. Review of present engineering education in Canada; Canadian university engineering courses; place of university in education; essentials in technical education; laboratory; lecture system; specialization; advanced degrees; practical experience; teaching staff; analysis of engineering courses in English-speaking universities and colleges of Canada.

REGISTRATION. Model Law for Registration of Professional Engineers and Land Surveyors. Civ Eng (N. Y.) v 2 n 8 Aug 1932 p 517–20. Text of form adopted and endorsed by Board of Direction of American Society of Civil Engineers.

RESPONSIBILITY. Engineer in a Changing Society, W. Wickenden. Elec Eng v 51 n 7 July 1932 p 465–71. Science a division of knowledge; group effort, not individual, becomes important; scientific knowledge exceeds social intelligence; responsibility of engineers; importance of agriculture; manpower vs. natural resources and machines; materials increase in importance; problems of youth increase; secondary education; new problems for capitalism, etc.

FLUE DUST

REMOVAL. Kneeland Street Plant Collects Flue Dust. Power v 76 n 2 Aug 1932 p 96–7. After 2½ yr of development work, Edison Electric Illuminating Co. of Boston has succeeded in removal 95% of solids from flue gases by improved scrubbing process.

FLUE-GAS ANALYSIS

MEASURING SOLIDS. Measurement of Solids in Smoke, E. C. Hutchinson. Power v 76 n 1 July 1932 p 24. Solids discharged from powerhouse stacks; efforts are being made to find some way of actually determining what solids are being discharged; duct models for gas flow.

FURNACES, ANNEALING

WIRE. Special Furnace Bright-Anneals Copper Wire in Steam Atmosphere, J. B. Nealey. Iron Age v 130 n 4 July 28 1932 p 143 (adv sec) 16. Design and operating details of furnaces installed at plant of Diamond Braiding Mills, Chicago Heights, Illinois.

FURNACES, FORGING

ECONOMY. Forging Costs Reduced by Use of Modern Furnaces, C. L. West and R. R. La Pelle. Heat Treating and Forging v 18 n 5 and 6 May 1932 p 315–18 and June p 373–5 and 378. Comparison of operating costs of oil-fired slot type furnace, rotary furnace, and gas-fired continuous pusher furnace of V-groove hearth type.

GAS. Efficient Forge Furnace, C. F. Clark. Heat Treating and Forging v 18 n 6 June 1932 p 371–2. Layout and operation of furnace for heating 300 to 550 lb of steel per hr with max consumption of 1800 cu ft of gas of 530 Btu; 3.3 cu ft of gas per lb of stock heated to forging temperature.

FURNACES, HEATING

GAS MEASUREMENT. Gasverbrauchsmessungen an einem Stossofen durch Mengenunterschieds-Messungen, W. Ruppert. Stahl und Eisen v 52 n 27 July 7 1932 p 665–6. Gas consumption measurements of ingot heating furnace by measurement of difference in flow; apparatus developed by "Hydro" Apparate-Bauanstalt, Duesseldorf, making use of well-known relay gas-meter principle.

FURNACES, INDUSTRIAL

CONTROL. Die feuerungstechnische und hydrodynamische Ueberwachung von Feuerungsanlagen, etc., C. Blacher. Feuerungstechnik v 20 n 7 July 15 1932 p 102–5. Thermotechnical and hydrodynamic control of furnace installed with use of comparatively simple apparatus, supplied by firm of Franz Hugershoff, Leipzig; example of its application to glass melting furnace.

FURNACES, METALLURGICAL

STOKERS. Mechanical Stokers for Metallurgical Furnaces, H. C. Armstrong. Iron and Coal Trades Rev v 125 n 3357 July 1 1932 p 10–11. Furnace stokers are not identical with boiler stokers, but are specially designed to meet different set of conditions; features of design, and results obtained with three types of stoker.

UTILIZATION. Ueber die guenstigste Ausnutzung lichter Ofenabmessungen, T. Stassinet. Stahl und Eisen v 52 n 28 July 14 1932 p 686–90. Best utilization of inside furnace dimensions with single and double layers of furnace charge and with multiple layers; examples.

GASOLINE ENGINES

MORRIS. Morris 5/12-H.P. Industrial Engine. Engineering v 134 n 3472 July 29 1932 p 124–6; see also Engineer v 154 n 3994 July 29 1932 p 116. Engine is of 4-cyl type, cylinders being cast monobloc with upper half of crankcase, and fitted with single detachable head; pistons, which are 57 mm in diam and have stroke of 83 mm, are die cast in special aluminum alloy.

[See also *Internal-Combustion Engines.*]

GEARS AND GEARING

GAGING. New Methods of Inspecting Gears for High-Speed Transmission, D. T. Hamilton. Machy (N. Y.) v 38 n 12 Aug 1932 p 932–8. Procedure followed in checking spur, helical, and herring-bone gears for shape, spacing, pitch diameter, and eccentricity on machine designed by Fellows Gear Shaper Co., Springfield, Vt.

MANUFACTURE. Modern Double Helical Reduction Gearing. Metropolitan-Vickers Gaz v 13 n 230 June 1932 p 278–83. Manufacture and testing of reduction gears of involute tooth form for high speed work made by Metropolitan-Vickers Electrical Co.; efficiency between 98 and 99%.

GOLD DREDGES

AERIAL TRANSPORTATION. Air-Transportation of Gold Dredges in New Guinea, C. A. Banks. Engineer v 154 n 3994 July 29 1932 p 107–8. Junker standard tri-motored G-31 passenger plane was adapted for carrying 7000 lb of freight; large hatch in roof of cabin allows of airplane being loaded by crane; equipment has been transported by two planes from coast to field without single accident; in tropical New Guinea airplanes will probably be more satisfactory and cheaper connection to coast than road.

HEAT PUMPS

USE IN REFRIGERATION. Heating With Refrigeration Equipment Cuts Current Costs, H. L. Doolittle. Power v 76 n 1 July 1932 p 29–31. Under most favorable conditions performance ratio of 2.32 is indicated by tests on first large-scale installation of refrigeration heating, that in Los Angeles office of Southern California Edison Co.; in this system heat is absorbed from outside air by cooler water, this heat is absorbed by refrigerant and then by condenser circulating water, and finally transferred to air going to building.

HYDRAULIC TURBINES

DESIGN. Calcul des cercles devannage des turbines hydrauliques, H. Meyer. Bul Technique de la Suisse Romande v 58 n 8, 9, and 10 Apr 16 1932 p 89–92 Apr 30 p 106–9 and May 14 p 115–17. Theory of design of hydraulic turbine gates and gate cylinders; calculation of resistance; deformation of cylinder.

HYDROELECTRIC POWER PLANTS

CANADA. Winnipeg Hydro System Power

Development at Slave Falls. Can Engr v 63 n 2 July 12 1932 p 5–10. Description of hydroelectric power plant of Winnipeg Electric Co. on Winnipeg River, comprising seven dams, one of which is of rockfill, 550 ft long, 80 ft high; sluiceway dam contains seven gates 21 ft × 50 ft; two vertical turbine units installed each having capacity of 12,000 hp; ultimate installation will be of eight units having total capacity of 96,000 hp.

SWITZERLAND. Das Projekt fuer ein Kraftwerk Rheinau der Stadt Winterthur, der Aluminium-Industrie, A.-G., Neuhausen und der Elektrizitaets-A.-G. vorm. Schuckert & Co., Nuernberg, J. Buechi, and E. Affeltranger. Assn Suisse des Electriciens—Bul v 23 n 14 July 8 1932 p 341–3. Plan of Rheinau hydroelectric power plant for city of Winterthur of Aluminium-Industrie A.-G., Neuhausen and Elektrizitaets-G.-G., previously Schuckert & Co., Nuernberg; useful head at turbine shaft from 6.7 to 12.4 m; min output at 100 cu m per sec 9480 kw, max 31,200 kw.

INDUSTRIAL MANAGEMENT

TEXTBOOKS. Industrial Management, E. C. Rosbins and F. E. Folts. N. Y. and Lond. McGraw-Hill Book Co., 1932. 757 p diagrs charts maps tables, $5. Case system is applied to beginner's course in industrial management; 117 cases presenting various aspects on problems, such as specialization, diversification, and integration; application of fundamentals to managerial control of raw materials. labor, plant, and equipment. Eng. Soc. Lib. N. Y.

INDUSTRIAL PLANTS

DESIGN. Rationalization Layout for Plant Making Heavy Machinery. Iron Age v 130 n 3 July 21 1932 p 105–6. New plant built by Lake Erie Engineering Corp., Buffalo; layout consists of 115- by 500-ft building, containing foundry and machine shop end to end, with smaller pattern storage and general utility building parallel, separated from main building by raw material and flask storage yard spanned by 20-t crane.

ELECTRIC DRIVE. Selecting Right Drive for Each Machine, V. A. Hanson. Machy (N. Y.) v 38 n 12 Aug 1932 p 942–4. Cost comparison of machine drive for plant having typical metal working operations to perform including production of stampings, forgings, and building of tools and dies.

RECORDING INSTRUMENTS. For Plant Diagnoses—Electrical Instruments, G. A. Van Brunt. Maintenance Eng v 90 n 8 Aug 1932 p 322–3. Review of 16 specific cases where power and money have been saved in installation of electrical recording instruments; most plants can cut costs by more efficient operation of power consuming equipment and elimination of practices or conditions that lead to waste of power and to production irregularities.

STORES CONTROL. Pin Point Planning, E. B. Headden. Factory & Indus Mgmt v 83 n 6 June 1932 p 233–4. Simple stock and production control for small plant, that of Motor Improvements Inc., Newark, N. J.; control board is well-planned system of minimum and sub-minimum markings; with it, ordering becomes automatic and just enough materials to supply current needs can be kept on hand.

INDUSTRIAL RELATIONS

EMPLOYEE COUNCIL. Columbia's Model A—Successful Experience in Industrial Democracy, H. P. Dutton. Factory & Indus Mgmt v 83 n 6 June 1932 p 258–60. Since plan of Columbia Conserve Co. of Indianapolis was put into effect, company made profit in every year with one exception; management was entrusted without reservation to council which meets weekly and in which every employee regardless of rank has equal vote; such intimate details as status of bank loans, costs of operation, sales policy, are discussed without reservation.

INDUSTRIAL TRUCKS

LIFT. Safety in Handling Materials, R. L. Studley. Safety Eng v 63 n 6 June 1932 p 255–6. Particulars of equipment manufactured by Lewis-Shepard Co., including jacklift, singlelift, footlift, and platforms.

INTERNAL-COMBUSTION ENGINES

DETONATION. Effect of Jacket and Valve Temperatures on Knock Ratings of Motor Fuels, F. H. Garner and E. M. Dodds. Engineering v 134 n 3469 and 3470 July 8 1932 p 45–7 and July 15 p 60–2. Work undertaken at Engine Laboratories of Anglo-American Oil Co., London, with object of investigating effect of varying certain engine conditions, more especially temperatures, upon knock ratings of wide range of motor fuels; engines used were early form of air-cooled Delco lighting set and water-cooled testing set developed later.

Pinking in Internal Combustion Engines, K. Schnauffer. Fuel v 11 n 8 Aug 1932 p 298–302. Results of investigation; intensity of pinking depends on amount of unburned gas mixture remaining when pinking is set up and on composition (fuel-air ratio) of mixture; ionization current increases when pinking occurs; when pinking is absent, after-burning occurs until exhaust valve opens. Indexed in Engineering Index 1931 p 763 from VDI Zeit Apr 11 1931.

ENTROPY DIAGRAMS. Is-Diagramme fuer Verbrennungsgase und ihre Anwendung auf die Verbrennungsmaschine, W. Pflaum. Berlin, VDI-Verlag, 1932. 45 pp illus tables charts, 17 diagrs in poc et, 7.90 rm. Diagrams similar to Mollier diagrams for fuels used in internal combustion engines; tables hold for pressures from 0.1 to 200 atm and 0 to 3000 C; processes that best utilize available energy established for various types of two-cycle and four-cycle engines. Eng. Soc. Lib. N. Y.

LATHES

CAPSTAN. Capstan Lathes with All-Electric and Single-Pulley Headstocks. Engineering v 134 n 3472 July 29 1932 p 135–6. Two lathes made by H. W. Ward & Co, Birmingham, England, are of same capacity, height of centers being 5½ in.; they differ in drive for headstock, one having all-electric head, while other has single-pulley drive.

DIAMOND-TOOL. Diamond Tool Lathe. Engineering v 134 n 3470 July 15 1932 p 82–3. B.S.A. lathe is development of 6-in. by 6-in. multi-tool production lathe of B.S.A. Tools, Ltd.; pistons having diameters from 2 to 5 in., with max skirt length of 3½ in. may be dealt with.

HIGH-SPEED. Heavy-Duty Roughing Lathe Uses High-Speed Cutting Tools, S. Weil. Iron Age v 130 n 3 July 21 1932 p 109–10. High-speed lathe, designed by Schiess-Defries, is equipped with three front and three rear carriages, and bed, which is 6-ft 10½-in. wide, has four ways, two for front and two for rear carriages; 350-hp variable-speed motor with speed range of 400 to 1100 rpm is employed for main drive.

LOCOMOTIVE BOILERS

EVAPORATION. Economic Evaporation in Locomotive Working, R. Sumiyama. Japanese Gov Ry—Bul v 20 n 21 June 10 1932 6 p. Particulars of method of economic evaporation as applied to actual locomotive working and also with results of tests with this method which were carried out at Hakodate engine terminal. (In Japanese.) See Engineering Index 1932 p 817.

LOCOMOTIVES

GARRATT. Beyer-Garratt Express Passenger Locomotive. Ry Gaz v 57 n 6 Aug 5 1932 p 168–70. Locomotive, built for Paris, Lyons & Mediterranean Railway (Algerian system) standard gage lines, has been specifically designed for high-speed service; dimensioned outline diagram of 4-8-2 plus 2-8-4 Beyer-Garratt express locomotive; cylinders 19¼ by 26 in.; coupled wheels 5 ft 10⅞ in.; boiler pressure 227.51 lb per sq in.; total weight in working order 197.7 tons.

LUBRICATION

CUTTING FLUIDS. Choice of Cutting Fluids Simplified by Research, J. Geschelin. Automotive Industries v 67 n 2 July 9 1932 p 36–9. Characteristics of commercial cutting oils with particular regard to soluble oils and sulphurized oils.

FOUNDATION. Foundation of Effective Lubrication. Lubrication v 18 n 8 Aug 1932 p 85–96. Importance of design and installation; necessity for primary inspection; operating factors; effect of pressure; influence of temperature.

PRESSURE. Oil Pump for Central Lubrication. Engineering v 134 n 3471 July 22 1932 p 109–10. Simple mechanically operated pump for pressure distribution introduced by Tecalemit, Ltd., known as "Brentford" mechanical lubricator.

PROGRESS. Lubricants, E. A. Evans. Instn Petroleum Technologists—J v 18 n 103 May 1932 p 362–75. Review of progress during 1930 and 1931. Bibliography.

MACHINE SHOPS

POWER TRANSMISSION. Modern Power Transmission Layout in Hand Screw and Turret Lathe Department, V. A. Hanson. Mill & Factory v 10 n 6 June 1932 p 38–9. Eight distinct advantages are found in model installation shown.

MACHINE TOOLS

CASTINGS. Verschleissversuche an einer Werkzeugmaschine mit auslegierter Fuehrungsbahn, G. Schlesinger. Giesserei v 19 n 29/30 July 22 1932 p 281–4. Abrasion tests on machine tool in which defective spots in slideway have been filled in; holes in flat cast-iron slide filled in with cast-iron solder; results of tests shown in diagrams.

MACHINERY

MAINTENANCE AND REPAIR. Selection of Spare Parts, R. Digby-Smith. Mech World (Lond.) v 92 n 2374 July 1 1932 p 12–13. Considerations which should be given by purchaser in selection of spare parts for machines or other pieces of apparatus in plant.

RUBBER MOUNTING. Use of Rubber in Machine Design. India-Rubber J v 84 n 1 July 2 1932 p 20–3. Characteristics of various typical applications of rubber mountings; dimensional diagrams of rubber extensions on mountings.

MAGNETISM

FORMULA FOR HYSTERESIS. I limiti di applicabilita' della formula di Steinmetz, I. Lucchi. Elettrotecnica v 19 n 16 June 5 1932 p 418–21. Comparative critical review pointing out limits of applicability of Steinmetz formula for hysteresis.

MATERIALS HANDLING

EQUIPMENT. Duckbill Reciprocating Conveyor for Handling Ore and Coal, A. C. Jebens. Eng Progress v 13 n 7 July 1932 p 150–1. Notes on equipment manufactured at Bochum, Germany.

MATERIALS TESTING

CLINOMETERS. Festigkeitspruefung mit Hilfe des Klinometers, A. U. Huggenberger. Schweiz Bauzeitung v 99 n 12 Mar 19 1932 p 151–4. Method of determining strength of metallic or masonry structures by reading deflection with aid of clinometers.

FATIGUE. Dynamic Testing of Materials, R. E. Peterson. Elec J v 29 n 8 Aug 1932 p 377–9 and 13. Representative portion of fatigue test facilities of one large industrial company is shown in illustrations. Bibliography.

LABORATORIES. De inrichting van het laboratorium voor photo-elastisch spanningsonderzoek der Technische Hoogeschool te Bandoeng en de aldaar gevolgde werkwijze, C. G. J. Vreedenburgh. Ingenieur v 47 n 29 July 15 1932 p B131–41. Equipment of laboratory of photoelastic stress analysis of Institute of Technology in Bandoeng, Dutch East Indies, and methods of investigation; various equipment illustrated. Bibliography.

METALLOGRAPHY

PHOTOMICROGRAPHS. Photomicrographs at Low Magnification, J. O. Lord. Am Soc Steel Treating—Trans v 20 n 1 July 1932 p 1–26. Apparatus and methods that may be used in making photomicrographs at magnifications ranging from 1 to 20 diam; three classifications of subject are considered: polished surfaces by vertical illumination; rough surfaces of low relief; rough surfaces, or objects of high relief.

METALS

DEEP DRAWING. Deep-Drawing Qualities of Thin Sheets, J. Cunningham. Mech World v 92, n 2376 July 15 1932 p 53–4. In deep-drawing expansion test annular test pieces having central hole are drawn into cup while outer rim of cup is firmly clamped in circular flat-faced die material being drawn radially from center and central hole enlarging until cracks appear round inner edge; percentage expansion of this hole and load required to produce deformation are measured.

Untersuchungen ueber Tiefziehen, W. Riem. Zeit fuer Metallkunde v 24 n 7 July 1932 p 157–61. Investigations of deep drawing; results of experiments on annealed sheets, 0.5 and 1.5 mm thick, of aluminum and copper alloys, including brass and bronze; method of calculating deep drawing capacity.

ELASTIC HYSTERESIS. Elastic After-Effect in Metals, M. F. Sayre. J Rheology v 3 n 2 Apr 1932 p 206–11. Description and tentative explanation of phenomenon; measurements of elastic after-effect in tension; presence of elastic after-effect due to thermal causes and existence of mechanical hysteresis loop due to same causes.

HARD FACING. Reduce Wear for Economy. Oxy-Acetylene Tips v 11 n 6 June 1932 p 83–7. Application in various industries of hard-facing by means of oxyacetylene process.

HARDENING. Terminology of Hardening, R. H. Greaves. Metallurgist (Supp to Engineer) July 29 1932 p 110. It seems that terms precipitation or dispersion hardening and artificial aging should be discouraged; if hardening is produced by quenching from temperature at which solid solution is stable, it should be called quench hardening; if by tempering, or reheating below temperature at which solid solution is stable, it should be called temper hardening, terms aging and age hardening being retained to describe case involving tempering at atmospheric temperature.

X-RAY ANALYSIS. Die Durchlaessigkeit von Kupfer, Aluminium und Blei fuer gefilterte heterogene Roentgenstrahlen. M. Widemann. Metallwirtschaft v 11 n 28 July 8 1932 p 383–6. Permeability of copper, aluminum, and lead for filtered heterogeneous X-rays, determined with aid of photographic indication; method of determining permeability values; results of graphic analysis; practical examples.

METALS CUTTING

PRODUCTION TABLES. Estimating Machining Times for Automatics, H. Watson. Engineering v 134 n 3472 July 29 1932 p 121–2. Tables presented relate to production on fairly efficient machines of Browne and Sharpe type in average factory, using high-speed cutters, but do not give minimum times possible where rough work is turned out under intensive specialist operation.

MICROMETERS

OPTICAL. Microlux Optical Micrometer. Engineering v 134 n 3470 July 15 1932 p 79. Microlux micrometer manufactured by Fritz Werner, Berlin, for gaging of finished parts within fine limits; fundamental features are that manual touch is replaced by constant mechanical pressure, reading is very greatly magnified, and it can be distinguished without aid of eyepiece.

MOTOR TRUCKS

DIESEL. French Diesel Operator Shows 8 to 15% Savings, P. M. Heldt. Automotive Industries v 66 n 26 June 25 1932 p 918–20. Superior economy of oil-engines in city and highway hauling service, weighed against higher initial cost, taxes, and other expenses on basis of paper by M. A. Audouin before French Society Automobile Engineers.

NITROGEN

SOLUBILITY. Solubility of Nitrogen in Water at 25° C from 25 to 1000 Atmospheres, R. Wiebe, V. L. Caddy and C. Heins, Jr. Indus & Eng Chem v 24 n 8 Aug 1932 p 927. Absorption coefficient of nitrogen in water at 25 C and 1 atm partial pressure is 20% less than that of hydrogen, but at 1000 atm nitrogen is less than half as soluble as hydrogen.

OPEN-HEARTH FURNACES

PHYSICAL CHEMISTRY. Ueber das Verhalten des Gasschwefels und die Schwefelbilanz im basischen Siemens-Martin-Ofen, F. Eisenstecken and E. H. Schulz. Stahl und Eisen v 52 n 28 July 14 1932 p 677–86. Behavior of sulphur gas and sulphur balance in basic open-hearth furnace; preliminary tests; determination of sulphur content of waste gases; method of gas sampling; effect of air and gas chambers; effect of sulphur gas on bath.

REFRACTORY BRICK. "Duoflex" Regenerator Bricks. Iron and Coal Trades Rev v 124 n 3356 June 24 1932 p 1030–1. Application of special type of brick to open-hearth furnace regenerators.

WASTE-HEAT UTILIZATION. Surplus-Heat Recovery From Open-Hearth, W. Gregson. Iron and Coal Trades Rev v 124 n 3354 June 10 1932 p 954–6. Application of surplus-heat boilers in steelworks; any open-hearth furnace operating on fuel gas, or combination of gases giving similar mean analysis of fuel, affords case for economic surplus or waste-heat recovery by steam-raising in properly designed boiler plant with lowering of cost of production of prime product.

ORIFICES

TESTING. Orifice Used to Reduce Fluctuating Pressure, A. A. Fette. Power Plant Eng v 36 n 16 Aug 1932 p 624–5. Results of investigation with various sizes of orifices at Cincinnati General Hospital; piping arrangement for low pressure steam supply; size determined by trial; characteristics of records obtained.

OSCILLOGRAPHS

SWEEPING CIRCUITS. Ein Kipprelais sehr kurzer Schaltzeit, M. Knoll and M. Freundlich. Elektrotechnische Zeit v 53 n 28 July 14 1932 p 669–73. High-frequency sweeping circuit for cathode-ray oscillograph; supply from a-c network; sweeping speed from 1 to 3 $\times 10^{-7}$ sec; accelerating plate voltage 300; constructional details.

PHOTOELECTRIC CELLS

CAESIUM. Caesium-Oxygen-Silver Photoelectric Cell, C. H. Prescott, Jr., and M. J. Kelly. Bell System Tech J v 11 n 3 July 1932 p 334–67. Technique permitting formation of caesium-oxygen-silver photoelectric cells under controlled conditions; design details; design factors; characteristics in tables and curves.

INDUSTRIAL APPLICATION OF. Photo-electric Cells. Elec Rev v 111 n 2851 July 15 1932 p 81–2. Some applications illustrated, i.e., amplifier, counting device, operating alarm, and automatic lighting control.

PILES

STEEL, CORROSION OF. Steel Sheet Piling in Good Condition After 19 Years, J. S. Unger. Steel v 91 n 4 July 25 1932 p 26–8. Result of inspection of U. S. Steel Sheet Piling M-101, 12-in. section weighing 35 lb. per ft, rolled in 1912 by Carnegie Steel Co., Pittsburgh.

PLATES

STRESSES. Statische untersuchung quadratischer, allseitig elastisch eingespannter Platten, M. Ritter. Schweiz Bauzeitung v 99 n 11 Mar 12 1932 p 131–5. Theoretical mathematical analysis of stresses in square plates elastically fixed along entire perimeter.

POWER PLANTS

EFFICIENCY. Weitere Anwendungsmoeglichkeiten des Ausnutzungsfaktors der Betriebszeit, W. Weingaertner. Elektrotechnische Zeit v 53 n 28 July 14 1932 p 673–4. Supplement to article previously indexed from issue of Mar 31 1932, on further possibilities of electro-economical concepts of load factor and plant factor.

OPERATION. Einregelung von Wirklast mit und ohne Fahrplanregler beim Parallelbetrieb grosser Kraftwerke (Elektrowerke-AG), E. Buchaly and K. Leopold. Elektrotechnische Zeit v 53 n 28 and 31 July 14 1932 p 665–9 and Aug 4 p 738–40. Problems of power output control of power plants; new type of load schedule regulator which enables complete control of output regardless of heavy and short-time load impulses of street cars and interurban line loads.

PUMPS

FEEDWATER. Die Zulaufhoehe fuer Kesselspeisepumpen, K. Gruen. Zeit. des Oesterreichischen Ingenieur und Architekten Vereines v 84 n 5–6 Feb 12 1932 p 23–4. Derivation of differential equations and formulas for computation of head required to insure uninterrupted operation when valve opens suddenly.

Efficient Suction Head for Centrifugal Pump Operation, A. Peterson. Power v 76 n 2 Aug 1932 p 69–71. Head required on suction of centrifugal pumps for satisfactory operation at different water temperatures, such as found in boiler feedwater applications and hot-well service.

RAILS

MANUFACTURE. Overcoming Shattercracks in Rail Manufacture. Can Chem and Met v 16 n 5 May 1932 p 141–2. Outline of process developed and patented by I. C. Mackie; discovery is that shatter cracks may be fully eliminated by retarded cooling in black heat range.

REFRIGERATION

PRINCIPLES. Principles of Refrigeration, W. H. Motz. 3 ed. Chicago, Nickerson and Collins Co, 1932. 1019 p, illus diagrs charts tables, $7.50. Practical, non-mathematical treatment of principles underlying operation of ice making and refrigerating machinery; properties of usual refrigerating media; construction and application of apparatus; adopted by National Association of Practical Refrigeration Engineers for study in national lectures courses. Bibliography. Eng. Soc. Lib. N. Y.

ROLLING MILLS

ANNEALING COSTS. Berechnung der Gluehereikosten eines Kaltwalzwerkes, K. Veit. Stahl und Eisen v 52 n 27 July 7 1932 p 667. Calculation of annealing costs of cold rolling mill; formulas and tables.

ELECTRIC CONTACTORS. Heavy Duty Contactors for Mill Service, D. L. Pierce. Blast Furnace & Steel Plant v 20 n 8 Aug 1932 p 649–51. Improvement of design of arcing parts on d-c contactors; higher blowout field strength; temperature of core of arc; there is decided tendency in present-day design to locate stop on same side of main bearing pin as moving parts and armature.

RUBBER

LATEX. Latest Trends in Latex Processes, G. W. Trobridge. Rubber Age (N. Y.) v 31 n 8 July 25 1932 p 321–3 (discussion) 323. Forms of concentrated latex; electrodeposition method; latex produces superior quality goods; round and uniform cross-section of latex gives substantially greater strength than that of corresponding square material; wide field of possible application.

SAWS, METAL-WORKING

METAL WORKING. Two Hot Sawing Machines. Engineer v 154 n 3993 July 22 1932 p 93. Machines manufactured by S. Russell and Sons; 36-in. machine is suitable for use in small forges, rolling mills, and stamping shops; smallest machine of series has 18-in. diam blade, and max cutting capacity of $2^3/_4$ in. diam; bed is mounted on pedestals and serves as work table and slide.

SCALES

REMOTE CONTROL. Remote Control of Weighing Appliances, A. B. Jacobus. Scale J v 18 n 10 July 1932 p 5 and 6. Review of various characteristics pertaining to equipment and methods of remote control for scale operation; advantages of control. Before Nat. Scale Men's Convention.

SCREW MACHINES

AUTOMATIC LOADERS. Automatic Loaders for Individual Machines, C. O. Herb. Machy (N. Y.) v 38 n 12 Aug 1932 p 902–5. Hydraulic and pneumatic equipment devised by Seneca Falls Machine Co., Seneca Falls, N. Y., for individual machines.

SHEET-METAL WORKING

WELDING. Autogenes Schweissen ohne Abschraegen der Blechraender, C. F. Keel. Zeit fuer Schweisstechnik (J de la Soudure), v 22 n 5 May 1932 p 128–9. Procedure in oxyacetylene welding of sheet and plates up to thickness of 10 mm without previous beveling of edges.

SPRING STEEL

TESTING. Federstaehle, E. Houdremont and H. Bennek. Stahl und Eisen v 52 n 27 July 7 1932 p 653–61 (discussion) 661–2. Composition, manufacture, and behavior of alloy and unalloyed spring steels with rolling and heat treating; static and dynamic properties, particularly, torsional strength and influence of skin produced by rolling; evaluation of torsional strength in design of springs; acceptance tests.

Magnetic Test Locates Flaws in Valve Springs, A. V. De Forest. Iron Age v 130 n 3 July 21 1932 p 107 and (adv sec) 18. Airplane-engine valve springs were found to have better resistance to fatigue if they had polished surfaces than if they had been sand blasted or etched; therefore it was advantageous to find test for defects that left surface unimpaired; such test, magnetic dusting, is employed to locate flaws and is giving satisfactory results.

SPRINGS

DESIGN. Die Berechnung zylindrischer Schraubenfedern, O. Goehner. VDI Zeit v 76 n 30 July 23 1932 p 735. Supplementary note to article on design of closely wound cylindrical springs, previously indexed from issue of Mar 12 1932.

HELICAL. Chart for Use in Designing Helical Springs, A. Hutton. Machy (N. Y.) v 38 n 12 Aug 1932 p 893–4. Alignment chart for designing helical springs made from round bar stock based on max shear stress of 70,000 lb per sq in.

STEAM POWER PLANTS

CHARTS. Operation Charts, G. P. Pearce. Power Plant Eng v 36 n 16 Aug 15 1932 p 627–8. Work your formulas into graphs and save time in calculating reports; practical advantages of operating charts; air and oil consumption chart.

GREAT BRITAIN. Extensions to Hackney Power Station. World Power v 18 n 103 July 1932 p 30–3. Latest extensions form complete self-contained unit designed on modern lines; comprises three large automatic stoker-fired boilers, 30,000-kw turbo-alternator, twin condenser, and switchgear; new boiler house and turbine room; coal handling equipment.

HEAT LOSSES. Erfahrungen aus Industriekraftwerken, O. Berner. Waerme v 55 n 26 and 27 June 25 1932 p 447–51 and July 2 p 464–6. Experiences in industrial power plants; increased heat losses due to industrial depression and measures for overcoming them; experiences in industrial district of Magdeburg and statistical data of boiler, power, and heating plants.

SOUTH AFRICA. More Generating Plant for Salt River. S African Engr and Elec Rev v 23 n 170 June 1932 p 3 and 5–7. Growth of Capetown load, and need for extending Salt River, which will contain South Africa's first 33,000-v alternator; features of generating and boiler plants.

STATION PRACTICE. Steam Power Station Practices, A. D. Bailey, A. G. Christie, and F. A. Allner. Elec World v 100 n 4 July 23 1932 p 112–17. Survey of present practices; data on operating performance and design; trends and recommendations for future developments; tables.

UNITED STATES. Central Station Plant and Performances, A. G. Christie. Power v 76 n 1 July 1932 p 38–9. Review of latest American practice, submitted by American Committee of International Electrical Congress, Paris, July 4 to 19, 1932.

STEAM TURBINES

CONTROL. Ueber Entlastungsversuche und Aenderungen der Regelorgane der Dampfturbinen in den Grosskraftwerken Boehlen und Hirschfelde, H. Zeuner. Elektrizitaetswirtschaft v 31 n 12 June 30 1932 p 271–6. Load-reducing tests and change of regulating elements of steam turbines in super power plants in Boehlen and Hirschfelde; it is shown to what extent control equipment is affected by parallel operation and what changes were to be made after tests.

DESIGN. Berekening van stoomverbruik en vermogen eener stoomturbine, werkende onder andere omstandigheden (begindruk, begintemperatuur en tagendruk) dan die, waarvoor zig gebouwd werd, L. H. De Langen. Ingenieur v 47 n 30 July 22 1932 p W115–18. Calculation of steam consumption of steam turbine operating at different initial pressure and temperature and different back-pressure than original; theoretical mathematical analysis.

HIGH-CAPACITY. Betriebserfahrungen mit Dampfturbinen grosser Leistung, K. Dolzmann. Elektrizitaetswirtschaft v 31 n 12 June 30 1932 p 253–7. Operating experience with high capacity steam turbines; extracts from report of Mechanical Engineering Committee of Verein Deutscher Elektrizitaetswerke, on experience with 127 units of 10,000 or more kw, totaling 3,000,000 kw; put into service after January 1925.

LJUNGSTROEM. Die Ljungstroem-Turbine in Deutschland, P. Reuter. Elektrizitaetswirtschaft v 31 n 12 June 30 1932 p 264–70 1 supp plate. Ljungstroem turbine in Germany; manufacturers Internationale Ljungstroemturbinen-Union A.G.; number of units in operation since 1925; operating experience and data; comparative tables of steam consumption; efficiency; etc.

TESTING. Testing Non-Condensing Turbines for Efficiency, G. B. Randall. Power v 76 n 2 Aug 1932 p 74–5. Simple method of testing suggested applicable whenever enthalpy of exhaust steam from turbine can be determined.

STEEL

COLD WORKING. Eliminating Cold-Working Strains in Drawing Rustless Steels, C. C. Snyder. Iron Age v 130 n 5 Aug 4 1932 p 180–1. Notes pertaining to great degree of hardness developed in certain rustless steels by cold working; properties of 18–8 steel (8% chrome and plain carbon) before and after cold working.

Permanent Bending of Cold Steel, A. W. Knight. Mech World (Lond) v 92 n 2374 July 1 1932 p 1–3. Result of experiments carried out in workshop to discover forces set up in rolling cold steel within plastic range; magnitude of forces involved in bending cold-steel plates or bars.

CORROSION. Corrosion of Mild Steel and Alloys by Hydrogen Sulfide at 500° C and Atmospheric Pressure, A. White and L. F. Marek. Indus & Eng Chem v 24 n 8 Aug 1932 p 859–61. Mild steel is rapidly attacked by hydrogen sulphide at 500 C and atmospheric pressure; under same conditions aluminum is very slightly attacked even after exposure for 3 weeks; high-chromium steels (12 to 20% chromium) resist corrosion; presence of high proportions of nickel are detrimental to corrosion resistance imparted to alloys by chromium.

HARDENING. Das Haerten des Stahles, F. Reiser and F. Rapatz. 8 ed. Liepzig, Arthur Felix, 1932. 200 pp illus diagrs charts tables, 12 rm. Manual intended for toolmaker rather than skilled metallurgist; directions for hardening, tempering, and annealing steel for all usual purposes; theoretical principles explained; methods, equipment and testing. Eng. Soc. Lib. N. Y.

HEAT TREATMENT. Causes and Elimination of Quenching Cracks in Steel, A. Sourdillon. Iron Age v 130 n 3 July 21 1932 p 102. Causes of internal cracks in quenched steel and precautions to be observed in reducing their frequency. Indexed in Engineering Index 1931, p 1383, from Revue de Metallurgie Nov 1931 under heading of Steel Hardening.

Peut-on éviter les tapures, J. Chanzy. Revue de Métallurgie v 29 n 6 June 1932 p 281–300. Possibility of avoiding scaling of steel at heat-treating temperatures; cause of scaling; stresses; alpha variations; speeds of cooling; influence of thickness and of composition of metal; results of tests. See also discussion by A. Sourdillon, p 301–5 of same issue.

METALLOGRAPHY. Micro-Structure of Hardened Carbon Steel, H. E. Publow and W. P. Fitz-Randolph. Mich Eng Experiment Station—Bul N 45 v 7 n 7 Apr 1932 19 p. Various theories on hardness of martensite; structures discussed in this article were produced by quenching eutectoid plain carbon steels at various points on dilatation curve; explanation of photomicrographs presented. Bibliography.

OXIDATION. Beitrag zur Kenntnis der Schutzwirkung der beim Zundern auf Stahl gebildeten Oxydschichten, H. von Schwarze. Mitteilungen aus dem Forschungs-Institute der Vereinigte Aktiengesellschaft Dortmund v 2 n 12 1932 p 263–77. Contribution to problem of protective action of oxide coatings formed with scaling on steel; determination of speed of oxidation at low temperatures; hammer scale will protect steel effectively only when it forms with uniform adherence and thickness on surface of steel; investigation of hammer scale on iron-chromium-aluminum alloys.

TEMPERATURE EFFECT. Characteristics of Deformation of Steel Under Constant Load at Elevated Temperatures, G. R. Brophy. Am Soc Steel Treating—Trans v 20 n 1 July 1932 p 58–66 (discussion) 66–72. Purpose of investigation is to present qualitatively results of study of deformation and to suggest possible short-time testing method; results support idea that creep and elastic hysteresis, if not same, are closely related; this probably holds only within strain-hardening range.

STOKERS

LIGNITE. Stand der Rostfeuerungen fuer Rohbraunkohle, Adomeit. Braunkohle v 31 n 28 July 9 1932 p 521–35 and (discussion) 535–6. Status of stoker-fired furnaces for crude lignite: examples of modern types of stokers.

THERMOCOUPLES

TESTING. Tests of Balanced Thermocouple and Filter Radiometer as Standard Ultra-Violet Dosage Intensity Meter, W. W. Coblentz, R. Stair and J. M. Hogue. U S Bur Standards—J Research v 8 n 6 June 1932 p 759–78. Erythema produced by radiometrically measured amount of heterogeneous ultra-violet radiation compared with radiation emission line of mercury which is used as standard; close agreement found between physiologically and radiometrically determined erythemogenic efficiency of all sources examined.

TUBES

MANUFACTURE. Die Herstellung von nahtlosen Roehren aus hochschmelzenden Stoffen, J. A. M. van Liempt. Metallwirtschaft v 11 n 26 June 24 1932 p 357–9. Manufacture of seamless tubes of high melting metals; process with which it is possible to make small and large tubes for scientific and technical purposes; although process is applicable to all metals, description is confined to tungsten.

MILLS. Les procédés de laminage réducteur, pour la fabrication des tubes sans soudure. Génie Civil v 100 n 26 June 25 1932 p 648–9. Methods of rolling seamless tube without use of mandrel, starting with thick-walled tubing; Stuting-Papen and Stuting processes.

TUNGSTEN-CARBIDE TOOLS

CUTTING ECONOMY. Economic Factors Affecting Use of Tungsten and Tantalum Carbide Tipped Milling Cutters, M. Romaine. West Machy World v 23 n 6 June 1932 p 219–23. Examples from automobile (Nash) engine production line illustrate feasibility of applying tungsten or tantalum carbide to specific operation; feed, speed, and output for milling operations.

TURBO-GENERATORS

STARTING. Inbetriebsetzen und Anfahren von Dampfturbosaetzen, F. Gropp. Elektrizitaetswirtschaft v 31 n 12 June 30 1932 p 258–64. Putting into operation and starting of steam turbogenerators; experience of BEWAG power plants in Berlin where pronounced peak loads prevail and which for this reason may be of value to other plants.

STATORS. Turbo-Alternator Stator Leads. Engineer v 154 n 3992 July 15 1932 p 69. Stator for one of 67,200-kw turbo-alternators installed in London Power Co.'s new station at Battersea; leads have been brought out at side, instead of at bottom.

UNEMPLOYMENT RELIEF

UNITED STATES. Emergency Relief and Construction Act of 1932, J. P. Hogan. Civ Eng (N. Y.) v 2 n 8 Aug 1932 p 510–11. Analysis of "Normal Program of Public Works Construction to Stimulate Trade Recovery and Revive Employment;" Federal credit for production public works.

VENEER

HISTORY. Comparing Ancient with Modern Veneering Methods, A. W. Anesley. Veneers v 26 n 8 Aug 1932 p 6–7. Review of author's experiences pertaining to veneering methods; surfacer characteristics; superiority of corestock produced in present-day mill rooms.

VENTURI METERS

TESTS. Untersuchung ueber die Croesse des Durchflusskoeffizienten von Venturiduesen, A. Engler. Schweiz Bauzeitung v 99 n 18 Apr 30 1932 p 225–8. Theoretical mathematical analysis and experimental tests of discharge of large venturi tubes; factors affecting discharge; discharge coefficients of several types of European venturi tubes.

WATER-TREATMENT PLANTS

FLOCCULATORS. Flocculator Is Important New Device for Water Treatment, A. Anable. Contract Rec v 46 n 29 July 20 1932 p 815–16. Design of Dorrco flocculator and description of eight duplex units installed at Hamilton, Ont.

WELDING

CONSTRUCTION USE. Ausgewaehlte Schweisskonstruktionen, Bd. 3. Rohrleutungsund Behaelterbau, Holler and A. D. Fink. Berlin, VDI-Verlag, 1932 88 pp illus diagrs. 12.50 rm. Atlas of 88 plates illustrating application of modern welding in construction of containers and pipe lines; photographs and drawings present wide variety of apparatus, illustrating advantages of welding in manufacture of equipment for chemical factories, steam plants, etc. Explanations of plates given in English. Eng. Soc. Lib. N. Y.

NITROGEN EFFECT. Age Hardening Phenomena in Typical Fusion-Weld Metal, F. R. Hensel and E. I. Larsen. Am Soc Steel Treating—Trans v 19 n 7 May 1932 p 639–64 (discussion) 664–72. Age hardening caused by precipitation of iron-nitrogen compounds; changes in hardness, magnetic properties, electrical conductivity and tensile properties and structural changes; properties of arc welds compared with those of gas welds, low carbon steel, and ingot iron.

STEEL STRUCTURES. What Products Should Be Welded? E. H. Hubert. Factory & Indus Mgmt v 83 n 6 June 1932 p 241–3. Comparison of welded steel and cast-iron products; table showing products in which welded steel has advantageously replaced castings.

TESTING. Proving Reliability of Welds. Elec Canada v 9 n 6 July 1932 p 8–9 and 29. Comparison of various methods of testing welded products, with special emphasis of Sperry electromagnetic method.

WIRE MILLS

ROD BAKERS. Steam Heated Rod Bakers, C. A. Bulkeley. Wire v 7 n 7 July 1932 p 224–5 and 238. Efficiencies and economies effected by Cramer six-track rod baker 60 ft long having capacity to treat 30 to 40 t of stock per hr, and requiring 4500 lb of steam per hr.

WIRE ROPE

MINE HOISTS. Extraction a grande profondeur par cables ronds en fil d'acier de grande résistance, etc. C. Vertongen. Revue Universelle des Mines v 75 n 1 and 2 July 1 1932 p 5–16 and July 15 p 41–9. Hoisting at great depth by means of circular rope of high-strength steel wire; light rope of bi-variable tension with reinforcement; calculation of cable weight.

Fabrication des cables d'extraction, Dufour. Revue de l'Industrie Minérale n 277 and 278 July 1 1932 p 273–80 and July 15 p 293–300. Manufacture and installation of mine-hoist rope; methods of inspection; trouble encountered in installation.

TORSION. Bad Torsion in Wire for Pit Ropes, R. Saxton. Engineering v 134 n 3471 July 22 1932 p 111. Chief fault is insufficient soaking during patenting or annealing process; given reasonable time in soaking process there is no doubt that present percentage of material condemned for bad torsion can be substantially reduced and, in writer's experience, this has been proved.

WOODWORKING MACHINERY

PLANERS. Various Types of Planers, J. E. Hyler. Wood-Worker v 51 n 5 July 1932 p 33–4. Practical review of author's experience relative to construction and operation of various types of planers.

X-RAY ANALYSIS

METHODS. Methods and Results of X-Ray Investigation of Sub-Crystalline Materials, F. D. Miles. Soc Chem Industry—J (Trans and Communications) v 51 n 31 July 29 1932 p 247T–54T (discussion) 254T–5T 1 supp plate. Significance of various types of diagrams which are yielded first of all by fibers and then by less individualized substances; two typical colloidal substances, rubber and nitrocellulose, are treated to illustrate general treatment.